State of Minnesota
Minnesota Pollution Control Agency

In the Matter of Proposed Amendments To Minnesota Rules Chapters 7050 and 7053 for Rule Amendments Governing Water Quality Standards- River Eutrophication, Total Suspended Solids and Minor Corrections. OAH Docket # 60-2200-30791, Revisor ID 4104.	Staff Post-Hearing Response to Public Comments January 28, 2014

MPCA Response to Comments Submitted During the Public Comment Period, at the Public Hearings and during the Post-hearing Comment Period.

I. Introduction

The Minnesota Pollution Control Agency (MPCA or Agency) noticed its intent to hold a hearing regarding proposed amendments to Minn. Rules ch. 7050 and 7053 in a Notice of Hearing published in the *State Register* on November 18, 2013 (38 SR 637). The Notice provided for the submission of comments from November 18, 2013, through the public hearings to be held on January 8, 2014, and also provided for a post-hearing comment of at least 5 working days after the public hearing. The comment period was extended by order of the Administrative Law Judge presiding at the hearing until 4:30 p.m. on January 28, 2014.

This rulemaking is limited in scope to the amendments proposed in that Notice under the authority of Minn. Stat. § 115.03, subds. 1 and 5 (2012)[1], and Minn. Stat. § 115.44, subds. 2 and 4. The scope is amendments to Minn. Rules ch. 7050 and 7053 for rule amendments governing water quality standards for river eutrophication (Eutrophication) and total suspended solids (TSS), and additional minor corrections.

The MPCA presented information demonstrating that the proposed amendments are needed and reasonable as required by Minn. Stat. § § 14.131 and 14.14, subd. 2, through an affirmative presentation of facts at the hearing, and in Hearing Exhibit HE-3, the Statement of Need and Reasonableness (SONAR) and the supporting exhibits to the SONAR.

This memorandum and Attachments I through VI, hereinafter called the Response, contain Agency staff responses to comments submitted during the public comment period, at the hearing and during the post-hearing comment period. The Response Attachments are:

[1]All citations are to Minnesota Statutes 2012 and Minnesota Rules 2013.

	A	B	C	D	E	F	G	H
1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
2	1/6/2014	HE-8-1		Brian Thompson	USEPA	USEPA Region V Water Division, Water Quality Branch, 77 west Jackson Blvd. Chicago, Il. 60604-3590 thompson.brian@epa.gov	"Add a definition of Eutrophication Standard."	MPCA agrees with adding the definition to the proposed rule.
3	1/7/2014	HE-8-2	1	Tim Sundby	Carver County	Address not provided	"The RNR for Carver Co is in error. The southern lobe of the Central RNR should be in the Southern RNR."	This portion of Carver County is mapped properly. Comment addressed in hearing transcript and Attachment II to MPCA's Post-Hearing Response to Public Comments.
4		HE-8-2	2	Tim Sundby	Carver County	Address not provided	"The Rosgen Classification of Natural Rivers system is a better basis for setting TSS/Nutrient standards."	Rosgen Classification is a good framework for physical management of streams and stream restoration. It is not an appropriate framework for setting eutrophication or TSS standards. Comment addressed in hearing transcript and Attachment II to MPCA's Post-Hearing Response to Public Comments.
5	1/7/2014	HE-8-3	1	Linda Holst	EPA Region V	USEPA Region V Water Division, Water Quality Branch, 77 west Jackson Blvd. Chicago, Il. 60604-3590	"Minnesota's proposed eutrophication standards under peer review for rivers and streams appear to be scientifically defensible, and EPA remains supportive of the state's efforts to develop eutrophication standards."	Comment in support of the proposed rule.
6	1/8/2014	HE-8-4	1	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"...we appreciate the efforts of the MPCA to replace turbidity ..with TSS. Ultimately this will be a more satisfactory approach."	Comment in support of the proposed rule.
7			2	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"The RNR are neither appropriate nor scientifically justifiable."	See Attachment II Response to Comments on Regionalization. This portion of Central River nutrient Region is mapped properly.

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8			3	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, Mn. 55379-1220	"We cannot discern from the technical analysis whether the actual values for the TSS standard are reasonable."	The technical analysis is reasonable and clearly summarized in the SONAR Book 3, pages 5-10.
9			4	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"Request a change to the RNR boundaries to move tributaries of the MN River to the South RNR instead of the Central RNR."	See Attachment II -Response to Comments on Regionalization. This portion of Central River nutrient Region is mapped properly.
10			5	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"Provide "modest" additional analysis to demonstrate the reasonableness of the actual values selected for the TSS standards."	The technical analysis is reasonable and clearly summarized in the SONAR Book 3, pages 5 - 10.
11			6	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"No validation was completed demonstrating that the TSS analyses were reasonable."	The 90th percentile TSS measurement of the reference streams forms the basis of comparison for the standard, and the average reference stream, by definition, then meets the standard. In addition, streams that are of better quality than those used as reference streams obviously would also meet the standard.
12			7	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"MPCA filtered the data to exclude stormflows but the standard is not written excluding stormflows. What would make us more comfortable would be validation using some of the reference and least impacted streams to see whether they meet the 10% exceedence level in the standard."	The commenter is incorrect in the assumption that the MPCA removed stormflows from the data that were used to develop the standard. It is true that, to ensure representativeness, datasets that were biased because they focused on storm events were removed from the overall analysis. The data that were actually used in the development of the standard, however, consist of measurements that are representative of the entire April through September period, including storm flows. It is the 90th percentile of these season-wide reference-stream measurements against which assessed streams are compared.

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13			8	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"MPCA is using an apples to oranges comparison re: stream percentiles."	The 90th percentile TSS measurement of the reference streams forms the basis of comparison for the standard, and the average reference stream, by definition, then meets the standard with its 10% exceedance level. In addition, streams that are of better quality than those used as reference streams obviously would also meet the standard with its 10% exceedance level. Also, see response to comment 3 of Randy Neprash testimony regarding projected percentage of stream segments exceeding the criteria in the standard.
14			9	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"RNR were not delineated for the purposes of regulating sediment and fail to recognize the critical processes that control naturally high sediment production rates in all tributaries."	RNR is based on ecoregion framework that was developed to "classify streams for more effective water quality management (HE-12, Omernik 1987). Ecoregions are not specific to only nutrients.
15			10	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"Minn. River tributaries are distinct from tributaries of the upper Miss."	Tributaries are mapped correctly based on ecoregion framework. See also Attachment III.
16			11	Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	"Tributaries of the lower Minn. exhibit dynamics similar to those of the rest of the Minn. River, so it should be classified as in the South RNR."	Tributaries are mapped correctly based on ecoregion framework. See also Attachment III.
17	1/8/2014	HE-8-5	1	Curt Sparks	Poplar River Management Board	Address not provided	"We believe the... Revision is necessary to address numerous problems with the application of the parameter Turbidity."	Comment in support of the proposed rule.
18			2	Curt Sparks	Poplar River Management Board	Address not provided	"PRMB is in support of eliminating Turbidity as a WQS."	TSS to replace Turbidity.
19			3	Curt Sparks	Poplar River Management Board	Address not provided	"Not certain that a TSS standard is needed."	Need for MN TSS Standard discussed in SONAR Book 3, pp. 5-6.
20			4	Curt Sparks	Poplar River Management Board	Address not provided	"No EPA Region V states have a TSS standard. Only SD has a TSS standard and it is different than the proposal. EPA does not have a TSS standard."	Need for MN TSS Standard discussed in SONAR Book 3, pp 5-6.

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21			5	Curt Sparks	Poplar River Management Board	Address not provided	"TSS is used as an effluent limitation and is in federal rules as a secondary treatment effluent limitation."	The current WQS for turbidity and the proposed WQS for TSS are both developed for the protection of aquatic life (Class 2 uses) in Minnesota. Discussion of effluent limits is beyond the scope of this rulemaking.
22			6	Curt Sparks	Poplar River Management Board	Address not provided	"TSS standard is not needed because other limitations indirectly control the impacts of TSS on the environment."	Need for TSS Standard discussed in SONAR Book 3, pp 5-6.
23			7	Curt Sparks	Poplar River Management Board	Address not provided	"PRMB supports geographic standards but "one standard for all 2A wastes does not recognize the unique water quality differences in mountain streams on Lake Superior.""	The current WQS for Turbidity includes a separate standard for protection for trout waters that applies to Class 2A streams in Minnesota. This current standard and the proposed TSS standard were developed to protect trout and other cold water organisms. The biological analysis of the impacts of TSS were performed using statewide cold water stream data in part because of the relatively small dataset for these streams. However, many of the important cold water species (e.g., trout, sculpins) inhabit both northern and southern coldwater streams so it is reasonable that similar thresholds would be protective in these streams. In addition, the available TSS data from the Lake Superior coldwater streams indicated that these streams have lower levels of TSS than their southern counterparts. Therefore, the proposed TSS criteria that apply to the Lake Superior coldwater streams are reasonable to protect both northern and southern coldwater streams. Further discussion of effects of suspended solids on trout is found in the Technical Support Document (TSS-1).
24			8	Curt Sparks	Poplar River Management Board		"...the proposed TSS standards for all Class 2A streams does not recognize the natural background conditions of North shore streams."	The commenter is correct that TSS levels are generally lower during winter months and higher during the storm events and floods that are part of natural background conditions. These facts, however, do not mean that the result is more violations nor impairments. The reference streams to which assessed streams are compared likewise have TSS levels that are generally lower during winter months and higher during storm events and flood conditions. Natural background, season, and hydrologic conditions are all taken into account in the standard and are reflected both in the data used to measure reference conditions and in the data then used to measure assessed conditions.

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25			9	Curt Sparks	Poplar River Management Board		"Request considering North Shore streams as a unique area-either through a different limitation or "excluding date from the database when extreme conditions exist.""	The North Shore area is certainly not unique in terms of having extreme conditions with elevated TSS levels. The fact that TSS concentrations are higher during storm events, floods, the summer season, etc. is true of both reference streams and streams to be assessed, and is accounted for within the standard. See further the responses to comment HE-8-5-8 above and HE-8-5-15 below. In addition, extreme, atypical conditions can be taken into account as mitigating circumstances during the water-quality assessment process if necessary.
26			10	Curt Sparks	Poplar River Management Board	Address not provided	PRMB supports in principle the approach that the TSS standard should be based on aquatic life.	Comment in support of the proposed rule.
27			11	Curt Sparks	Poplar River Management Board	Address not provided	"The term "of the time" is not defined."	The words "of the time" have the comonly understood meaning that TSS concentrations cannot exceed the standard more than 10% of the time of the April-through-September periods representing current conditions.
28			12	Curt Sparks	Poplar River Management Board	Address not provided	"How many measurements are used in the averaging dataset?"	Details regarding the number of years and number of measurements and exceedances are specified in the MPCA's Assessment Guidance rather than in the rule itself. Specifically, data are used from the most recent 10 years and generally must include at least 20 independent and representative measurements from at least two separate years. In contrast to the assumption made in the comment, one of nine samples exceeding the standard is not sufficient for a determination of impairment.
29			13	Curt Sparks	Poplar River Management Board	Address not provided	"PRMB does not object to an assessment season."	Comment in support of the proposed rule.

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30			14	Curt Sparks	Poplar River Management Board	Address not provided	"Averaging a dataset that excludes winter compliant periods will over emphasizes periods of extreme conditions and will result in great percentage of violations."	Including data from winter months would not have the effect the commenter suggests. Winter data would be included not only for assessed streams but also for reference streams. The result would be lower 90th percentile TSS concentrations for both assessed streams and reference streams, and the resulting numbers in the TSS standard would then also be lower. The percentage of violations would remain the same. See also response to comment HE-8-5-8.
31			15	Curt Sparks	Poplar River Management Board	Address not provided	"Flood conditions will cause the proposed standard to be exceeded. A more geographic-specific approach (which is not proposed) would eliminate this problem."	TSS concentrations are indeed generally higher during flood conditions and storm events, not just in the North Shore area, but across the state. As with the inclusion of winter data, the exclusion of flood and storm-event conditions would have the effect of lowering the 90th percentile TSS concentrations for both assessed streams and reference streams, and would also lower the numbers in the TSS standard. Again, the percentage of violations would remain the same. See also response to comment HE-8-5- 8.
32			16	Curt Sparks	Poplar River Management Board	Address not provided	"Suggest excluding storm events from the database with greater than 1 year occurrence in 24 hours."	See response to HE-8-5- 8 and comment HE-8-5-15.
33			17	Curt Sparks	Poplar River Management Board	Address not provided	"Exclude floods above a one-year frequency."	See response to HE-8-5-8 and comment HE-8-5-15.
34			18	Curt Sparks	Poplar River Management Board	Address not provided	"Exclude atypical conditions (fire, tornadoes)."	Atypical conditions such as "forest fires, slope failures, tornadoes and accidents" can be taken into account as mitigating circumstances during the water-quality assessment process.
35			19	Curt Sparks	Poplar River Management Board	Address not provided	"Assessment database should be at least one year -up to 3 years and for fewer than 20 samples, combine consecutive years."	No. See response to HE-8-5-12.
36			20	Curt Sparks	Poplar River Management Board	Address not provided	"Database should be at least 20 separate measurements at least 5 days apart."	No. See response to HE-8-5- 12.

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37			21	Curt Sparks	Poplar River Management Board	Address not provided	"Data for use impairment should not be based on storm event monitoring for North Shore streams."	The data are not based on storm-event monitoring, but do take TSS concentrations during storm events into account. See responses to comments HE-8-5-8 and HE-8-5 -15.
38			22	Curt Sparks	Poplar River Management Board	Address not provided	It is unreasonable to require 90% compliance under all hydrologic conditions."	90% compliance is not required under every hydrologic condition. It is over the course of the whole season and overall conditions that 90% compliance is required; it is precisely because of varying, sometimes extreme conditions that 90% compliance is a reasonable criterion.
39			23	Curt Sparks	Poplar River Management Board	Address not provided	"Want the rule and the supporting SONAR to thoroughly address the assessment process for determining compliance. "	See response to HE-8-5- 12.
40	1/8/2014	HE-8-6	1	Stephen Nyhus	Minnesota Environmental Science and Economic Review Board ("MESERB")	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Memo 1 and 1A present and project costs based on the assumption that stabilization ponds will be required to meet a 1 mg/L discharge standard only."	This is a correct statement (see Exhibit EU - 41a).
41		HE-8-6	2	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"MPCA memos provide guidance for projecting capital and operating costs for a single facility at a given design flow- they do not provide guidance about how the costs might be extrapolated to state-wide impact of potential P discharge standards."	This is a correct statement. Extrapolating these estimates presumes MPCA knows exactly how many facilities will require lower limits and what those limits will be. This is done on a permit by permit basis.

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42		HE-8-6	3	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"There is no indication of the number of facilities that could be impacted."	For the purposes of the cost analysis, a range of effluent limits for dischargers was provided. Effluent limits developed on the basis of river eutrophication standards will be derived on a case-by-case basis and multiple factors for any given facility will be taken into consideration. Limits have not yet been derived for each individual facility statewide. This process will be realized during the five year permit cycle immediately following formal rule adoption.
43		HE-8-6	4	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Low, average and high cost ranges seem appropriate for design flow ranges from .5 to 20 MGD."	Comment in support of the Agency's cost analysis. See SONAR Book 2, page 120, and Exhibit EU - 41a: Table A for information on facility costs.
44		HE-8-6	5	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"The 0.2 to 0.5 MGD estimates seem low based on our experience with these smaller facilities."	This comment did not suggest different estimates based on references. MPCA made a reasonable effort to estimate these costs. See SONAR page 120 and Exhibit EU - 41a: Table A for information on facility costs.
45		HE-8-6	6	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"The capital and other operating costs are taken from various sources so it is difficult to assess the validity of the data as well as the regression analysis presented in Memo 1A."	This comment is correct as MPCA file sources were used (See Exhibit EU - 41a narrative page 3, b. second paragraph).
46		HE-8-6	7	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"...costs related to the shortened solids storage capacity of the ponds to do not appear to be part of the cost evaluation."	This comment is correct as MPCA did not include shortened solids storage capacity in narrative cost estimate items (See Exhibit EU - 41a narrative page 3, b. first paragraph).
47		HE-8-6	8	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"The costs in Memo 2, Table 2B appear to be: old, need to consider more than O & M related to chemicals and land application, and do not consider the need for additional settling capacity or sludge storage. Costs in this table appear too low."	MPCA made a reasonable effort to locate references that were available to use for the costs developed in Exhibit EU - 41c: Table 2B (one reference was 24 years old at the time the memo was written and the costs were translated into December 2010 dollars). The costs were developed assuming facility capital improvements were already completed (see narrative II.b. second paragraph page 3, Exhibit EU - 41c).

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48		HE-8-6	9	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"References to costs at WWTF outside of MN may not be relevant. Also construction and equipment are affected by cold climate factors."	MPCA made a reasonable effort to locate references that were available to use to develop the costs estimates. For a portion of Exhibit EU - 41c: Table 2C (capital costs from 0.2 to 20 mgd), information from Exhibit EU - 59 - a Wisconsin reference was used.
49		HE-8-6	10	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Alum and ferric treatment can be affected in lower temps, which will increase costs to MN WWTF."	MPCA made a reasonable effort to locate references that were available to use to develop the costs estimates. The Annual O & M cost estimates developed in Exhibit EU - 41c: Table 2C used information from Exhibit EU - 58, which did increase the target molar ratio for the chemical dosage rate.
50		HE-8-6	11	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"MPCA's tiered approach is flawed by assuming that future tiered technology is compatible with earlier tiered tech."	MPCA made a reasonable effort to locate references that were available to use to develop the costs estimates. The tier approach was adopted from those references: for example Exhibit EU - 58. A tiered approach was used to simulate the range of limits, not necessarily treatment technologies, which might be required for some dischargers following implementation of river eutrophication standards.
51		HE-8-6	12	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	""Design flow" is not defined and its use appears to alternate between interpolation and specific costs."	The design flow term was the most generic term that could be used because the references used usually had a slightly different terminology.
52		HE-8-6	13	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"In Memo 2, what is the 0.1 mg/L limit based on? Weekly/monthly/annual avgs?"	The 0.1 mg/L limit should be considered a calendar monthly average concentration effluent limit.
53		HE-8-6	14	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Were the facility limits based on compliance with a 0.1 mg/L P monthly concentration limit or was the limit based on summer average or annual mass limit?"	The 0.1 mg/L limit should be considered a calendar monthly average concentration effluent limit.
54		HE-8-6	15	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Memo 2, Table 2C seems to be based on costs from dissimilar climates and influent water quality."	MPCA made a reasonable effort to locate references that were available to use to develop the costs estimates. Exhibit EU - 41c used costs from a Wisconsin document (Exhibit EU - 58).

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55		HE-8-6	16	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"The low cost range in Memo 2,Table 2C does not appear to be appropriate for MN facilities in the 0.2 to 200 MGD flow range. To consistently achieve levels below 0.1 mg/L P, the high cost range would be most appropriate."	MPCA would expect the possible site specific costs for MN municipal facilities to be within the possible range of costs given in Table 2C (Exhibit EU - 41c).
56		HE-8-6	17	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Use of MN WWTF are cited under the cost estimate for 0.1 mg/L but the cited facilities are only required to meet 0.3 mg/L P."	The examples facilities cited in this sentence was only meant to reinforce the statement that for facilities with effluent limits below 0.5 mg/L, higher dosages of metal salts and filtration would be required. It did not mean that the Minnesota facilities cited currently had effluent limits of 0.1 mg/L, and were able to achieve those effluent limitation with their respective existing municipal wastewater facilities (see Exhibit EU - 41c II.b. second paragraph).
57		HE-8-6	18	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"For levels such as 0.1 mg/L, membrane filtration would be most applicable and should be assumed for the cost assumptions. Therefore, the high cost range listed in the MPCA cost memo is most applicable."	Exhibit EU - 41c states that filtration units including deep-bed granular media filters and/or microfiltration (microfiltration is one of the types of membrane filtration) processes could be used. The references used indicate that either technology may be able to produce effluent phosphorus concentrations to 0.1 mg/L or below. MPCA developed the range of costs in this table, and the cost at a specific site may indeed come at the high range at a site.
58		HE-8-6	19	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Cost estimates do not include site-specific factors (e.g.. land, soil correction...) and should be factored into the cost equations."	MPCA made a reasonable effort to locate references that were available to use to develop the cost estimates. The references used to develop these cost estimates did not include these site specific costs.
59		HE-8-6	20	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Without knowing how the limit will be applied (how it is averaged) makes it difficult to calculate the cost of compliance."	For the purposes of the cost estimate, it was assumed that treatment range categories would be evaluated on a monthly average basis.
60		HE-8-6	21	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Unintended consequences of compliance with stricter limits (e.g. greenhouse gas emissions)."	This is outside the scope of this rulemaking.

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61		HE-8-6	22	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"How and when will limits be implemented? Facilities need time to adjust."	Limits will be implemented in a similar manner to the existing lake eutrophication standards. Where existing facilities cannot meet new limits upon reissuance of a permit, a compliance schedule will be developed that is specific to the facility and water body of concern. In addition, facilities retain the right under existing State Rules to apply for a variance.
62		HE-8-6	23	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Cost estimates should assume use of membrane technology to meet 0.1 mg/L limit."	Exhibit EU - 41c states that filtration units including deep-bed granular media filters and/or microfiltration (microfiltration is one of the types of membrane filtration) processes could be used. The references used indicate that either technology may be able to produce effluent phosphorus concentrations to 0.1 mg/L or below.
63		HE-8-6	24	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Reference documents used for cost estimates need to be relevant to MN and current."	MPCA made a reasonable effort to locate references that were available to use to develop the costs estimates. Exhibit EU - 41c used costs from a Wisconsin document (Exhibit EU - 58).
64		HE-8-6	25	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"How the cost estimates will relate to state-wide cost impacts should be made available for review."	See response to HE-8-6-3.
65		HE-8-6	26	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"Comparison of two sets of phosphorus removal costs (Addendum)." We are uncertain how much more detail is required.	These are site specific costs from actual Minnesota wastewater facilities.
66		HE-8-6	27	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	"MPCA's stabilization pond costs do not represent ponds that must treat P levels below 1 mg/L. e.g. Albany's costs are 5 x the MPCA estimate."	The phosphorus limit for the city of Albany was derived from the existing lake eutrophication standard for a specific water body downstream of the outfall. It would not be appropriate to extrapolate the conditions and restrictions in this permit to the implementation of river eutrophic standards on a state-wide scale.
67		HE-8-6	28	Stephen Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	No comments summarized from the handout/Ohio EPA document.	

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68	1/8/2014	HE-8-7	1	Jill Thomas & Fred Corrigan	Asphalt pavement Association/Aggregate and Ready Mix Association (APA/ARMA)	Address not provided	"The development of these standards did not consider wet-weather conditions and should not be applied to stormwater discharges."	The proposed standards apply to ambient concentrations of pollutants in streams. Permit discharge limits may be derived to protect ambient conditions in receiving waters.The development of the standards, however, did in fact consider wet-weather conditions. Seasonal effects, rainfall events, and elevated stream, nutrient, and TSS levels are all part of the natural conditions for both reference streams and streams to be assessed. Measurements from wet-weather conditions do figure into reference-stream values and are likewise used in assessing streams when they are compared against those reference-stream values. Natural variability resulting from such things as seasonal effects and wet-weather condition underlies the use of the 90th percentile criterion in the TSS standard. See also response to comment HE-8-5, sub 8, 14-18, 21.
69		HE-8-7	2	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"There should be variances in the standards allowed for seasonal/annual variability in precipitation and temperature."	See response to HE-8-7-1.
70		HE-8-7	3	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"The (SONAR) economic review is generic and insufficiently supported with actual construction costs for industry specific industrial stormwater permit holders."	SONAR Book 3, pg. 23 states "MPCA staff compiled cost estimates to reduce TSS from industrial facilities by the following: (1) search of national public domain literature on estimating costs for TSS removal at various WWTPs; (2) information collected from suppliers and consultants on WWTPs that have completed construction of TSS removal facilities; and (3) information collected from suppliers and consultants on prepared cost estimates for contemplated future TSS removal-related construction projects."
71		HE-8-7	4	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"Ground truth study or addendum to the SONAR should be developed to better understand the economic impact related to all water discharges from all industrial facilities, not just the NPDES/SDS permits."	See response to comment HE-8-7-3.

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72		HE-8-7	5	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"Stormwater permits considered in the economic analysis should include MNG49."	Permit discharge limits may be derived to protect ambient conditions in receiving waters.
73		HE-8-7	6	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"The state should consider long term impact on MN economic viability and jobs. Existing and potential new business already consider the cost differential in MN vs neighboring states."	SONAR Book 1, pg. 27 (8) provides a discussion of "cumulative effect" of the amendments concluding that "the proposed amendments merely refine and amend the existing standards and do not add additional regulation that could be considered to be cumulative."
74		HE-8-7	7	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"SONAR does not state whether the TSS benchmark values are expected to change for MNG49 and MSGP. Seems to be a discrepancy between the SONAR statement that the "current effluent limits for stormwater permittees are close to what will be required to meet the proposed TSS.""	Influence of new TSS WQS on the stormwater TSS benchmark is out of scope for this rulemaking and will be determined as part of the process of permit renewal.
75		HE-8-7	8	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"Economy of scale causes small reductions in TSS to be increasingly difficult/expensive to meet."	Influence of new TSS WQS on the stormwater TSS benchmark is out of scope for this rulemaking and will be determined as part of the process of permit renewal.
76		HE-8-7	9	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"Meeting the current TSS benchmark is difficult given the nature of the (asphalt/ready-mix) business. "Failing to respond to a benchmark value exceedance is a violation of the permit."	Influence of new TSS WQS on the stormwater TSS benchmark is out of scope for this rulemaking and will be determined as part of the process of permit renewal.
77		HE-8-7	10	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"The TSS/Eutrophication standards will increase the number of impaired waters and thus the number of industrial stormwater permit applicants within 1 mile of impaired waters will increase. The effect on stormwater permits is insufficiently defined in the SONAR."	Influence of new TSS WQS on impaired water listing is discussed in the SONAR Book 3, pp. 24-25. The proposed TSS WQS is not expected to result in a significant increase in the number of impaired water listings.

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78		HE-8-7	11	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"More impairments mean that more businesses must make a faster response and faster responses are more expensive. These expenses are not reflected in the SONAR discussion of economic effect."	Influence of new TSS WQS on impaired water listing is discussed in the SONAR Book 3, pp. 24-25. The proposed TSS WQS is not expected to result in a significant increase in the number of impaired water listings.
79		HE-8-7	12	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"It is unclear how the proposed rules will affect monitoring requirements for the industrial stormwater permit holders."	This comment addresses implementation procedures which are out of scope for this rulemaking.
80		HE-8-7	13	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"It is unclear how the proposed rules will be considered in the updated MSGP, or the MNG49."	Influence of new TSS WQS on the stormwater TSS benchmark is out of scope for this rulemaking and will be determined as part of the process of permit renewal.
81		HE-8-7	14	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"It is unclear how the proximity of a facility to a trout stream could result in more restrictive benchmark monitoring value of 10mg/L TSS."	The value of 10 mg/L is proposed in this WQS for TSS as adequate for protection of trout streams. This would apply to all trout (Class 2A) waters in the state. There is no value more restrictive.
82		HE-8-7	15	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"Due to the potential impact on industrial stormwater permit holders, Minn. Rule 97C.005 subd. 2(d) should be revised to expand who is notified for waters proposed to be designated as trout streams or trout lakes. Similarly for ORVW."	This comment addresses implementation procedures, which are out of scope for this rulemaking.
83		HE-8-7	16	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"MPCA guidance for economic and social development impacts was developed for municipal WWTF and is not realistic or practical for industrial sites. Guidelines should be set to outline a streamlined approach instead of vague requirements."	This comment addresses implementation procedures, which are out of scope for this rulemaking.

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84		HE-8-7	17	Jill Thomas & Fred Corrigan	(APA/ARMA)	Address not provided	"MPCA should provide guidance about how to achieve standards when waters flow from or into a state with a different standard."	This comment addresses implementation procedures, which are out of scope for this rulemaking.
85	1/8/2014	HE-8-8	1	Kris Sigford	Minnes Center for Environmental Advocacy ("MCEA")	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"The proposed standards are ultimately based on policy decisions, not science, and these policy decisions resulted in standards that do not protect the state's rivers and streams."	The proposed standards are science based as described in Exhibit EU-1 and SONAR Book II. USEPA exhibit HE-8-3 and technical reviewers are in support. More detailed response in Attachment IV.
86		HE-8-8	2	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"My overall assessment is that, while the newly recommended criteria are improved over MPCA's previous draft criteria, they are still unreasonable and, therefore, they fall short of protecting Minnesota rivers from nutrient pollution. More protective criteria are needed."	The proposed standards are reasonable and will protect Minesota's streams from the effects of nutrient overenrichment. USEPA Region 5 is supportive of our approach for deriving the criteria as noted in HE-8-3.
87		HE-8-8	3	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA chose the (weight of evidence) alternative to derive numeric eutrophication criteria... and the initial steps MPCA followed were scientifically sound."	Comment in support of the scientific analysis.
88		HE-8-8	4	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA abandoned scientific validity in the next step it followed to derive the draft eutrophication criteria."	The use of the midpoint is scientifically valid for those datasets where no upper breakpoint was detected. In general, the midpoint was very similar to the changepoint thresholds - a method that Burkholder indicates in her comments is protective. Burkholder provided a couple of examples where these analyses were divergent, but these were exceptions. MPCA has determined the 25th percentile of thresholds for each method and no method was consistently more protective across all datasets (see attachment IV, Section 3). This suggests that they are comparable and that the resulting thresholds are protective.

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89		HE-8-8	5	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"The final step(s) MPCA used for final criteria derivation is so poorly explained that it is not possible to evaluate what actually was done and whether the approach was scientifically sound."	See Attachment IV, Section 4.
90		HE-8-8	6	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"In some analyses, one or both breakpoints were not clear. If the biological metric yielded both upper and lower breakpoints, MPCA made an arbitrary policy decision to use the midpoint between the as the threshold..."	This statement is incorrect. If both an upper and midpoint threshold was present and both were statistically significant, the upper breakpoint was used. This process is detailed in Figure 12 of Exhibit EU-1. Additionally, the threshold that was used is indicated in Appendix IV of EU-1.

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91		HE-8-8	7	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"This policy decision (the use of midpoints) is unreasonable because it will sacrifice many fish species and individuals by considering the midpoint concentration of higher pollution and greater biological decline relative to the actual protective threshold."	The development of river eutrophication criteria supports attainment of the CWA interim goal. This goal is defined in the CWA as: "wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water (U.S. Code title 33, section 1251 [a] [2])." The interim goal of the CWA does not require that all waters must meet goal equivalent to natural or pristine conditions. The goals Burkholder refers to matches the CWA objective ("restore and maintain the chemical, physical, and biological integrity of the Nation's waters;" U.S. Code title 33, section 1251 [a]). The statistical methods used by the MPCA were focused on setting minimum goals that support attainment of the CWA interim goal. This was accomplished by the use of metrics that are sensitive to eutrophication and by identifying thresholds that are consistent with attainment of the CWA interim goal. These relationships and the location of thresholds determined using Minnesota data closely correspond to the location of defensible thresholds derived from stressor-response response relationships in Stevenson, et al. (2008) (see Figure 2 in Stevenson, et al. [2008], as cited in the SONAR). These thresholds are consistent with the protection of fishable/swimmable" goals as defined by the interim goal of the CWA, and therefore, support Minnesota's aquatic life use goals. As a result, the threshold concentrations from each dataset are not intended to represent protection of the natural condition. Additionally, these do not represent pollute-down-to goals and waters that perform better than these goals should be protected.
93		HE-8-8	8	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"In deriving its proposed criteria, MPCA apparently gave the TP concentrations from its "midpoints" equal weight as the changepoint analysis-derived, much more protective concentrations. This approach by MPCA is irrational."	The process MPCA followed was valid for several reasons that have been described in more detail in our response to HE-8-8- 4 and 7; (1) the midpoint thresholds were similar to those derived from changepoint analysis; and (2) the reasoning behind the selection of the midpoint when the upper breakpoint is not present is supported by language in the Clean Water Act in regard to protection of the CWA interim goal.

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94		HE-8-8	9	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA should use the upper breakpoint from AQRS threshold analysis where both upper and lower breakpoints were clear and statistically significant."	MPCA agrees and this was the approach that the Agency followed.
95		HE-8-8	10	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"It appears MPCA aggregated all of the threshold concentration values... With this step, MPCA gave scientifically invalid, policy-based "midpoints" equal consideration with scientifically valid thresholds and changepoints."	See response to HE-8-8-4.
96		HE-8-8	11	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA brought these 25th percentile values into Regional line of evidence summary tables and compared them with values from a seriously flawed earlier MPCA study."	This statement is incorrect. The earlier study was not used to develop the proposed criteria. Rather it was used to give perspective to the criteria.
97		HE-8-8	12	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA did not include the 25th percentile values for all MN monitored streams (as recommended by EPA) although MPCA had those values available."	This is not a useful line of evidence for datasets where a valid "reference" condition can be identified. The use of the 25th percentile of all monitored streams requires an a priori decision that 75% of all monitored streams do not meet goals. This has no connection to attainment of goals or protection to aquatic life. In contrast, when sufficient reference site datasets are present, as in the North and the Central regions, the MPCA can use these as a line of evidence since these reference sites do represent sites that attain Minnesota goals. In the South region the MPCA did not have a good reference site dataset so did need to consider the 25th percentile of all monitored streams. This statistic is not as informative as the 75th percentile of reference sites, but it is useful when other, stronger lines of evidence are not available. The recommended criterion for the South region (150 µg/L) is very close to the 25th percentile of all monitored streams (146 µg/L).
98		HE-8-8	13	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"A clear description of the steps used to derive the draft criteria is lacking."	See Attachment IV, Section 4.

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99		HE-8-8	14	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"Because midpoints are erroneously combined with valid thresholds and changepoints, MPCA's step in bringing the 25th percentile values forward seems seriously misleading."	As described in MPCA responses to HE-8-8- 4 and 7, MPCA disagrees that the midpoints are invalid, and therefore, the use of the 25th percentile is not misleading.
100		HE-8-8	15	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"Other points that are indicated as valuable are not explained. Why did certain biological metrics that were strongly negatively correlated "disappear?"	The metrics that appear in Table 16 of EU-1 were based on a preliminary analysis of a relatively small dataset and was used as a screening tool. The relationships were evaluated with the larger biomonitoring and STORET datasets and some were found to not be as highly correlated as the final metrics. The analyses used to develop the recommended criteria were focused on the more sensitive metrics to ensure the criteria were protective.
101		HE-8-8	16	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA provided no explanation about how the final draft criteria were actually selected from the range of concentration thresholds."	See Attachment IV, Section 4.
102		HE-8-8	17	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA followed a flawed approach in its attempt to identify reference conditions and then used those reference values as a line of evidence to support the proposed standards."	The reference condition approach is not flawed. The Human Disturbance Score MPCA used to identify streams that have minimal impacts was effective at selecting streams that had low levels of human activity (see Attachment IV, Section 2) However, this approach was not equally effective for all the regions. For example in the North and Central regions this approach did identify streams that we consider minimally or least disturbed and as a result, the reference concentrations were useful in setting criteria. In contrast, the reference approach was not effective in the South region and as a result this line of evidence was given little to no weight in selecting the final criteria.
103		HE-8-8	18	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA ignored EPA's water quality based recommendations and instead based its "references or minimally disturbed conditions on two different approaches." Neither of the approaches is robust."	This statement is inaccurate. First, the MPCA did not rely on two different reference condition methods. One of these methods--cited as McCollor and Heiskary 1993- was not used to select criteria, but rather were used to give perspective to the final criteria. The reference condition approach that the MPCA did use was valid and protective (see response to HE-8-8-17).

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104		HE-8-8	19	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA's use of policy-based midpoints, led to high levels of eutrophication stressors that were evaluated as "acceptable.... The draft eutrophication criteria are much too high to protect Minnesota rivers from degradation...""	See responses to HE-8-8- 4 and 7.
105		HE-8-8	20	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"There is a strong precedent for use of biological data to support stressor-response criteria derivation, and setting protective river nutrient criteria would be a major step forward in restoring many Minnesota rivers from the detrimental impacts of eutrophication."	Comment in support of the proposed rule.
106		HE-8-8	21	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"... These policy decisions substantially increase the levels of nutrients that would be deemed acceptable. They are also much higher than the scientifically supported thresholds identified by additive quantile regression smoothing analysis..."	See MPCA Attachment III, which provides answers to the comments received at the time this MCEA correspondence was delivered to MPCA on September 12, 2012. MPCA responses were compiled as of October 2, 2012. This applies to comments HE-8-8-20-37, all of which are drawn from the 2012 MCEA submittal.
107		HE-8-8	22	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"In the SONAR MPCA lists seven external EPA reviewers and imply that they supported the proposed standards. What they supported was an earlier draft (2009) version, not the version that is proposed."	See MPCA Attachment III.
108		HE-8-8	23	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"The data are poorly described."	See MPCA Attachment III.
109		HE-8-8	24	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"The draft criteria are not based on reference conditions..."	See MPCA Attachment III.

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110		HE-8-8	25	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"The statistical approach of "midpoint interpolation" is not scientifically valid and not protective."	See MPCA Attachment III.
111		HE-8-8	26	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"The statistical methods and steps are poorly explained."	See MPCA Attachment III.
112		HE-8-8	27	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"MPCA's emphasis on pollutant tolerant metrics rather than sensitive metrics results in standards too high to protect sensitive biota."	See MPCA Attachment III.
113		HE-8-8	28	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"Wadeable and non-wadeable streams shouldn't be considered together."	See MPCA Attachment III.
114		HE-8-8	29	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"Total Chlorophyll is wrongly used to develop criteria for "corrected" chlorophyll resulting in a much higher living algal biomass than is acceptable."	Total Chl-a was used in the early work, consistent with what was found in the literature. As a result of discussions with MCEA and the desire to make river eutrophication standards consistent with lake standards, MPCA changed to corrected Chl-a (excludes non-viable portion of algae). All analyses that reference Chl-a were re-run, so all numbers are based on corrected Chl-a.
115		HE-8-8	30	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"Reference conditions are not compared to the draft criteria and do not support them."	See MPCA Attachment III.
116		HE-8-8	31	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"There are no total nitrogen criteria."	See MPCA Attachment III.
117		HE-8-8	32	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"There are no criteria that specifically protect high quality waters."	See MPCA Attachment III.

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118		HE-8-8	33	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"There are no criteria that specifically protect potable water supplies which are prone to toxigenic cyanobacteria outbreaks."	If deemed necessary, this can be addressed with site specific criteria. It is agreed that protection of water supplies is important; however there is no indication that current finished drinking water, derived from river water sources present a risk to consumers of the water (from the standpoint of blue-green algal toxins).
119		HE-8-8	34	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"There is no analysis to demonstrate whether/how downstream waters will be protected by the draft criteria."	As described in the SONAR Book II and Exhibit EU-1, the MINLEAP model serves as one basis for inferring standards are protective of lakes, is valid for NLF (North RNR) and NCHF (Central RNR) ecoregions as the stream values used are representative of minimally-impacted watersheds. However, that is not the case for WCP (South RNR). In the case of the South RNR, the proposed TP standard ranks near the 25th percentile and represents a low and protective value. In instances where proposed standard is not sufficient for protection of downstream resources (e.g. lakes), resource specific models developed for the purposes of setting water quality based effluent limits or TMDLs will determine the appropriate stream TP concentration. MPCA has made the case for downstream protection in the navigational pool and Pepin documents – based largely on the mechanistic modeling for the Lake Pepin TMDL. This is addressed in more detail in SONAR Book 2, pp. 83-84.
120		HE-8-8	35	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"Cold water (CW) streams are not protected by the draft criteria."	This will be addressed by Tiered Aquatic Life Uses (TALU) standards development if it is deemed to be an important issue. The proposed standards will apply to CW streams; however, there will not be many CW streams that grow excessive amounts of sestonic algae. If nutrient enriched, they are more likely to respond by exhibiting excessive levels of periphyton and the 150 mg/m2 numeric translator will address this.
121		HE-8-8	36	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"The numeric translator for periphyton is based on relatively sparse data."	It is reasonable based on an extensive review of the literature. While data may be sparse for MN, there is extensive data behind the numbers proposed in the literature as noted in Exhibits EU-1, and EU-52a,b.

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122		HE-8-8	37	Kris Sigford	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	"Compliance is poorly explained."	This is addressed more fully in SONAR Book 2, pp.89-90. The assessment approach is clearly presented. Monitoring is now underway to allow for assessment once rule promulgation is complete. Approach will emphasize non-wadeable streams; however, waters upstream from identified impaired stream reaches will be considered as part of the overall solution (TMDL).
123	1/9/2014	HE-8-9	1	Leslie Everett	University of Minnesota Water Resources Center	Address not provided	"It is not feasible to create water quality criteria for each combination of factors at the very fine scale with which they vary along a river system..." "It is instead necessary to *determine* the dominant controlling factors at a reasonable scale..." "This has been accomplished by the MPCA..."	Comment in support of the proposed rule.
124		HE-8-9	2	Leslie Everett	University of Minnesota Water Resources Center	Address not provided	"The dominant limiting factor for eutrophication in freshwater systems is the concentration of phosphorous limiting the growth of algae."	Comment in support of the proposed rule.
125		HE-8-9	3	Leslie Everett	University of Minnesota Water Resources Center	Address not provided	"There is a problem with trying to define river criteria at a finer scale than eco-regions.... Therefore I support the river criteria for TSS and Eutrophication as presented by MPCA as well as the methodology used to arrive at those criteria."	Comment in support of the proposed rule.
126	1/9/2014	HE-8-10	1	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"The City has no quarrel with the "need" to address excess phosphorous affecting Minnesota surface waters."	Comment in support of the proposed rule.
127		HE-8-10	2	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"The standards and analysis proposed by MPCA only intensify the focus on point sources as the only regulated discharges to surface waters."	Declarative statement. No response required.

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128		HE-8-10	3	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"...The MPCA's cost estimates drastically underestimate the financial impacts of the proposed standards."	See response to HE-8-10-8. The commenter does not provide data that can be used by the Agency in modifying the Agency's analysis or probable costs.
129		HE-8-10	4	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"The MPCA needs to go back and re-think the proper policy approach to address nutrient problems that are for the most part non-point in nature."	MPCA agrees that non-point sources are major source of excess nutrients in surface water; however, the policy question of regulating unregulated parties is outside the scope of this rulemaking.
130		HE-8-10	5	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"Will applicable river nutrient standards that,... may need to be met end of pipe with no dilution factor, render the entire TMDL process a waste of time and money?"	As part of the statewide approach to monitoring and assessing waters, approved TMDLs based on the turbidity standard and lake eutrophication standards will be evaluated on a rotating schedule to determine if the conditions of the TMDL and reductions called for are sufficient to also protect for river eutrophication standards and TSS. Turbidity TMDLs are developed using a TSS surrogate. In some cases the TSS surrogate developed for the TMDL will be sufficient to protect for the proposed TSS standards. In lake eutrophication TMDLs reviewed to-date, the TMDLs often require stream inflow phosphorus concentrations equal to or less than the proposed criteria. Many factors will be taken into consideration when determining appropriate effluent limits for a treatment facility. In particular, MPCA anticipates the relative contribution from a facility to a water body of concern will be used to determine the overall restrictiveness of a limit. Given that phosphorus is a ubiquitous pollutant and that most waters in exceedance of the standard will require reductions from multiple sources, it is not anticipated that the new standard or limit derivation method will eliminate the utility of the TMDL process.

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131		HE-8-10	6	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"When a TMDL "goalpost" is moved, what does that mean for those cities already trying to comply with existing wasteload allocations?"	See response to comment HE-8-10-5. The adoption of river eutrophication standards may, in some situations, result in water quality impairments that are more proximate to a given outfall. This, in turn, may result in the need for greater pollutant load reductions than what is called for in an existing far-field downstream reservoir TMDL. In this case, it is possible that a more restrictive limit would need to be implemented in the permit of concern. Nonetheless, given that RES are designed to be compatible with existing numeric lake eutrophication standards, the reductions called for in an existing lake eutrophication TMDL may also be consistent with a future river TMDL.
132		HE-8-10	7	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"The MPCA should address the question of equity between dischargers who are regulated under CWA and nonpoint and erosion who are not."	The proposed rule amendments implement Clean Water Act requirements to establish water quality standards. Regulation of dischargers is part of implementation of the standards through TMDLs, effluent limits and permits. The policy question of regulating currently unregulated parties is outside the scope of this rulemaking.
133		HE-8-10	8	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"The MPCA needs to be much more upfront about the amount of variability in probable compliance costs."	A full accounting of costs and benefits is not required to satisfy the legal requirements of Minn. Stat. § 14.131. The Agency undertook reasonable effort to ascertain the probable costs of complying with the proposed rule. SONAR Book 2 pps. 106-107, and pps. 112-127, and exhibits EU-41a-d and EU-42, describe the data used and the results of the effort undertaken by the Agency to ascertain the probable costs of complying with the proposed rule for identifiable categories of affected parties.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
134		HE-8-10	9	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"The estimates of "low" compliance costs are much too low. In Worthington, meeting a limit a tenth of that level would result in astronomical costs."	See response to HE-8-10-8. The commenter does not provide data that can be used by the MPCA in modifying the Agency's analysis of probable costs.
135		HE-8-10	10	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"It is not clear what compliance costs have been internalized into these estimates."	See response to comment HE-8-10-8.
136		HE-8-10	11	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"The cited strategies for reducing costs are a good effort, but will only help a few dischargers."	See response to comment HE-8-10-8.
137		HE-8-10	12	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"Lack of full and honest accounting of probable costs will lead cities into supporting a concept without understanding the price that will be paid."	See response to comment HE-8-10-8.
138		HE-8-10	13	Alan Oberloh	City of Worthington	P.O. Box 279, Worthington, MN 56187	"The proposed standards should be put on hold until the MPCA provides a full accounting of the costs and what the MPCA is going to do to address non-point sources of P."	See response to comment HE-8-10-8.
139	1/22/2014	HE-8-11	1	Linda Holst	USEPA	USEPA Region V Water Division, Water Quality Branch, 77 west Jackson Blvd. Chicago, Il. 60604-3590	"Based on our review of the information and analyses contained in the Technical Suport Document for TSS, the analyses used to derive the criteria from the available data appear to be scientifically defensible and the criteria appear to be sufficiently stringent to protect the uses of the waters to which they will be applied"	Comment in support of the proposed rule.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
140		HE-8-11	2	Linda Holst	USEPA	USEPA Region V Water Division, Water Quality Branch, 77 west Jackson Blvd. Chicago, Il. 60604-	"The establishment of ecoregional boundaries used in the criteria are supported by the science literature."	Comment in support of the proposed rule.
141		HE-8-11	3	Linda Holst	USEPA	USEPA Region V Water Division, Water Quality Branch, 77 west Jackson Blvd. Chicago, Il. 60604-3590	"MPCA's determination to replace Nephelopmetric Turbidity Units (NTU) standards with TSS standards appears to be scientifically defensible, as does the approach MPCA uses to identify thresholds and the subsequent criteria for the individual ecoregions."	Comment in support of the proposed rule.
142							**note: the citations to page and line numbers in the comments below refer to the transcript of the 1/8/14, 9:00 a.m. hearing**	**note: the citations to page and line numbers in the responses below refer to the transcript of the 1/8/14, 9:00 a.m. hearing.**
143			1	Testimony of Michael Schmidt	MCEA		Pg. 45, line 5 "MCEA feels that these standards are necessary for protecting Minnesota's waters and we commend MPCA for its significant efforts to address nutrient pollution and total suspended solids across the state."	Comment in support of the proposed rule.
144			2	Testimony of Michael Schmidt	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	Pg. 46, line 3 "These nutrient standards, numeric nutrient standards, will be very helpful in reducing nutrients across the state."	Comment in support of the proposed rule.
145			3	Testimony of Michael Schmidt	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	Pg. 47, line 22 "The statistical techniques that they used provide evidence that would support protective nutrient criteria. Unfortunately, MPCA deviated from those scientific methods by choosing, instead, to incorporate midpoint analysis between change thresholds."	These comments relate to comments presented in HE-8-8A and were addressed in the response to HE-8-8-1 to HE-8-8-19.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
146			4	Testimony of Michael Schmidt	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	Pg. 48, line 12 "Instead of taking the point at which the decline in sensitive fish individual begins, MPCA took the midpoint between that and where it levels off farther down, which ultimately allowed significant degradation of the biological metrics that it evaluated."	These comments relate to comments presented in HE-8-8A and were addressed in the response to HE-8-8-1 to HE-8-8-19.
147			5	Testimony of Michael Schmidt	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	Pg. 49, line 4 "So MCEA requests that the Agency use those upper breakpoints and change thresholds using the statistically valid methods that are recommended by EPA when calculating their criteria."	These comments relate to comments presented in HE-8-8A and were addressed in the response to HE-8-8-1 to HE-8-8-19.
148			6	Testimony of Michael Schmidt	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	Pg. 49, line 20 "It is not clear from their supporting documents how those decisions were made to increase the proposed standard from where the scientifically-valid changepoints were found to the ultimate criteria of 50."	These comments relate to comments presented in HE-8-8A and were addressed in the response to HE-8-8-1 to HE-8-8-19.
149			7	Testimony of Michael Schmidt	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	Pg. 49, line 25 "In addition, MPCA justifies its criteria by relying on streams that it characterized as reference streams, which are those that are minimally impacted, or not at all impacted by human eutrophication. EPA recommends using reference streams, but those streams need to be minimally impacted or not at all impacted, and MPCA's human disturbance index, which they use to identify those streams, does not consider significant non-point source contributions."	These comments relate to comments presented in HE-8-8A and were addressed in the response to HE-8-8-1 to HE-8-8-19.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
150			8	Testimony of Michael Schmidt	MCEA	26 East Exchange St.,Suite 206, St. Paul, MN 55101-1667	Pg. 51, line 2 "MCEA requests that the Agency use only the upper breakpoints where the upper and lower are found."	These comments relate to comments presented in HE-8-8A and were addressed in the response to HE-8-8-1 to HE-8-8-19.
151			1	Testimony of Randy Neprash	Minnesota Cities Stormwater Coalition	Stantec Consulting, 2335 Highway 36 West, St. Paul, MN 55113	Pg. 53, line 25 paraphrased - "curious how high flow conditions factored into the study and analysis."	See response at pg 57, line 20. See also the responses to comments HE-8-5-8 and HE-8-7-1.
152			2	Testimony of Randy Neprash	Minnesota Cities Stormwater Coalition	Stantec Consulting, 2335 Highway 36 West, St. Paul, MN 55113	Pg. 54, line 6 "Curious to know how particle size was factored into the study and analysis."	Soil type and particle size are part of the factors used in the delineation of ecoregions and are part of the reason for different standards in different parts of the state.
153			3	Testimony of Randy Neprash	Minnesota Cities Stormwater Coalition	Stantec Consulting, 2335 Highway 36 West, St. Paul, MN 55113	Pg. 54, line 17 paraphrased - "Wondering if there is info about the number of potential exceedences for the new TSS."	See response at pg.61, line 20. Of those stream segments (excluding large-river main-stems) currently having sufficient TSS data for assessment, 73 percent of streams in the southern region, 44 percent in the central region, and 28 percent in the northern region would not meet the criteria in the standard, and thus would potentially be considered impaired. These percentages, however, are from a limited data set and are not necessarily true of the larger body of streams in the three regions.
154			4	Testimony of Randy Neprash	Minnesota Cities Stormwater Coalition	Stantec Consulting, 2335 Highway 36 West, St. Paul, MN 55113	Pg. 55, line 1 paraphrased - "If a special standard is appropriate for the Red River, is a special standard also appropriate for the Minnesota River?"	See response at pg. 61, line 2.
155			5	Testimony of Randy Neprash	Minnesota Cities Stormwater Coalition	Stantec Consulting, 2335 Highway 36 West, St. Paul, MN 55113	Pg. 56, line 1 paraphrased - "Discuss why the standards for the lower Mississippi and Lake Pepin seem to ignore the influence of the Minnesota River."	See response at pg. 62, line 5.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
156			1	Testimony of Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	Pg. 64, line 4 paraphrased - "I request some sort of boundary change...with respect other tributaries to the MN. river that are located in the lower Minn. River basin. We disagree that those portions should be in the central region."	See response at pg. 73, line 17.
157			2	Testimony of Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	Pg. 64, line 22 "In the Minnesota River Basin, recent geomorphic phenomena have caused incision of the channel there, such that a number of the tributaries have high gradients near their mouth and have active knickpoints that are still naturally moving... And it is our finding that they really should be in the south...RNR."	High gradients near the mouth of streams is relevant to the management of a stream channel; however, it would not be a major determinant of which region these streams should be located in.
158			3	Testimony of Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	Pg. 65, line 9 "If you look at the information included in the texts of documentation for the River Nutrient Regions, there really isn't any geospatial statistical analysis in there showing that stuff clusters along the lines proposed in terms of water quality concentrations between regions."	The RNRs were based on ecoregions established by the U.S. EPA. Ecoregions were developed by the USEPA based on maps of land surface form, soils, potential natural vegetation and land use (HE-12, Omernik 1987). The approach used for defining ecoregions grew out of an effort to classify streams for more effective water quality management. MPCA does not see the need for further geospatial analysis.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
159			4	Testimony of Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	Pg. 65, line 21 "This is not a trivial issue. If you cross that line that is shown for Central Region to the south region, the standard changes by more than 100 percent, just because of some line."	The line is not arbitrary but founded in sound analysis. See response to comment #3 of Paul Nelson testimony.
160			5	Testimony of Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	Pg. 66, line 7 "I don't understand all the analysis, and it occurs to me that some validation is in order.... When they did the analysis for coming up with the values for the TSS standard, they used different percentile ranges for Central Region and South Region, I think 30 to 50 percentile range ranking in one area and 10 percentile to 40 percentile rankings in another area, and they also groomed or filtered the data set to take out nonrepresentative data.... So by grooming that out, I question whether that sort of would set the bar a little lower on whatever percentiles are calculated from that data set because you're taking out the higher values."	See response to comment HE-8-4-7.

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161			6	Testimony of Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	Pg. 67, line 16 "My point, further, would be, though, is that when they wrote the standard, they used a different criteria. The numbers that they analyzed were calculated based on ranked percentiles of the referenced streams. The standard was written to be a 90th percentile or 10 percentile exceedance of a data set for a stream. So I'm concerned that we're dealing with apples and oranges, and that's why it would be very important to have this validation, and what I would request for.... is to take those referenced least impacted streams and apply the criteria, the 10 percentile."	See response to comment HE-8-4-8.
162			1	Testimony of Tim Sundby			Pg. 68, line 21 "We feel that looking at the data that this was based upon, this -- Carver County is an error and should be located in the South RNR.... it was also recognized that the whole southern lobe of the Central RNR should be reallocated to the South RNR."	Addressed in HE8 8-2 subcomment 1 and Attachment II.
163			2	Testimony of Tim Sundby	Carver County		Pg. 69, line 4 "There was a gap in the research, scientific research going into the -- into the proposed nutrient and suspended solids standards. In reviewing all the technical analysis that was done, I do not see any reference to the fluvial geomorphology of streams."	Land surface form, or geomorphology, is one factor that went into the mapping of ecoregions. Fluvial geomorphology was not specifically addressed in development of the river eutrophication and TSS standards.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
164			3	Testimony of Tim Sundby	Carver County	Address not provided	Pg. 69, line 17 "The standards have been based on ecoregions, and it does not take into account actual streams of stream slope, bed material, width/depth ratios, entrenchments or actual stream channels, whether it's single- or multi-channel. These characteristics are actually in use right now by the Minnesota Department of Natural Resources for their work on stream restoration across the State of Minnesota, and they use that as their basis to return the stream to which would be towards these standards."	Ecoregions were developed by the USEPA based on maps of land surface form, soils, potential natural vegetation and land use (Exhibit HE-12, Omernik 1987). The approach used for defining ecoregions grew out of an effort to classify streams for more effective water quality management.
165			4	Testimony of Tim Sundby	Carver County	Address not provided	Pg. 71, line 4 "Our region does align with the Western Cornbelt Region. So we would like to state that we should switch our region from Central to the South."	Based on the RNR approach the Carver County and surrounding areas are characterized properly (See Attachment II).
166			5	Testimony of Tim Sundby	Carver County	Address not provided	Pg. 71, line 9 "We recommend use of the Rosgen Classification in their seven -- their eight major types as a basis for standards, setting standards. These take into account the stream slope, stream bed material, entrenchment, width/depth ratios and velocity that is more representative across the whole state that could be applied for the whole state and not just ecoregions."	Addressed in subcomment 2 8E-8-2. Rosgen good for management purposes but not as a basis for water quality standards development.
167			6	Testimony of Tim Sundby	Carver County		Pg. 71, line 17 "Using Rosgen system... would take away boundary issues, and also, it would help to align restoration work within the State of Minnesota between people that are trying to meet these new standards and what the standards are."	See response at pg. 74, line 24 and Attachment II.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
168			7	Testimony of Tim Sundby	Carver County	Address not provided	Pg. 71, line 22 "If we try to put a standard that is not typical for a stream, what a natural stream would be, we're actually adding a human constraint, which will set the stream into a static motion, which is not -- which would not be achievable and results into some catastrophic failures down the road."	Comment is unclear.
169			1	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 79, line 16 "The PRMB is in support of eliminating turbidity as a water quality standard. We are not, however, certain that total suspended solids is needed, either."	See response to comments HE-8-5-2 and HE-8-5-3.
170			2	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 80, line 13 "We ask that the need for the TSS water quality standard Minnesota be carefully weighed in these proceedings."	See response to comment HE-8-5-6.
171			3	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 80, line 21 "The PRMB supports a geographical approach because waters across the State have water quality characteristics that are based on local conditions. However, the current turbidity standard and the proposed TSS standard of 10 milligrams per liter as it applies to Class 2A waters is statewide with no geographic consideration. The PRMB believes that there are ecoregion differences in Class 2A waters that should be considered in the standards revision. Specifically, the mountainous steep-sloped streams in the North Shore of Lake Superior exhibit unique different characteristics than other 2A -- or Class 2A streams across the state. One standard for all 2A waters does not recognize the unique water quality differences in mountain streams of Lake Superior."	See response to comment HE-8-5-7.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
172			4	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 81, line 16 "It is well established that natural conditions in mountainous stream watersheds is a major factor in defining background conditions. Topology, soils, stream grade, vegetation cover, climactic conditions are all different in the North Shore."	See response to comment HE-8-5-8.
173			5	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 81, line 23 "The North Shore streams have elevated turbidity levels as natural conditions during rainfall runoff events, and I cite the assessment of Representative Lakeshore -- Lake Superior Basin Tributaries, MPCA 2003. Therefore, the proposed uniform TSS standard for all Class 2A streams did not -- does not recognize the natural background conditions of North Shore streams."	See response to comment HE-8-5-8.
174			6	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 82, line 18 "TSS has no effect on vegetation that's not present. The extreme velocity of flow on the North Shore streams removes fine sediment bed load quickly. Shortly after rainfall events, the clarity of the water returns as available sediment in the bed of the stream is removed. The lower segments of the North Shore Class 2A streams where the impaired AUID stretches exist do not have the same aquatic impacts from TSS as other streams in the State."	See response to comment HE-8-5-8.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
175			7	Testimony of Curtis Sparks	Poplar River Management Board		Pg. 83, line 3 "The PRMB requests that MPCA consider North Shore mountainous streams as a unique geographic area that has background conditions warranting geographic considerations in the new TSS standards. These considerations could be different averaging percentage, a different limitation, or excluding data from the database where extreme conditions exist."	See response to comment HE-8-5-9.
176			8	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 83, line 13. "The aquatic life, water quality standards TSD document identifies aquatic life impacts that are primarily chronic in nature. Chronic impacts are not instantaneous, and therefore, the standard should not represent an instantaneous numerical standard."	See response to comment HE-8-5-12.
177			9	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 84, line 11 "In all cases, the words "of the time" are used but not defined. What is the time? Is it monthly? Is it a year? Is it 10 years or the entire known data set?"	See responses to comments HE-8-5-11 and HE-8-5-12.
178			10	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 84, line 15 "Also, how many measurements are used in averaging the dataset? If nine samples are used, it takes only one sample above the standard to exceed 10 percent of the time. Neither rule nor the SONAR provides clarification on this issue."	See response to comment HE-8-5-12.

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179			11	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 84, line 20 "The PRMB does not object to an assessment season...... The proposed assessment season contain stakes only one sample above the standard to exceed 10 percent of the time. Neither rule nor the SONAR provides clarification on this issue."	See response to comment HE-8-5-12.
180			12	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 85, line 18 "The rule, therefore, proposes differing standards, assessment seasons, averaging periods for all categories except Class 2A streams. The PRMB requests the North Shore streams be given regional-specific requirements."	See response to comment HE-8-5-7.
181			13	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pg. 86, line 2 "If the assessment database is based on storm event monitoring, as was done in, quote, "An Assessment of Representative Lake Superior Basin Tributaries," MPCA 2002, it does not represent the overall condition of the stream."	See response to comment HE-8-5-21.
182							Pg. 86, line 21 "The PRMB recommends that the MPCA consider making clarifying language to the TSS standard for Class 2A waters of the North Shore to include: A. Exclude storm events greater than one year occurrence in a 24-hour period from the assessment database. Exclude flood-flow conditions where a one-year flood frequency -- above a one-year flood frequency from the assessment database.	See response to comments HE-8-5-8, HE-8-5-12, HE-8-5-15 and HE-8-5-18.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
183			14	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Exclude conditions that are not typical or out of the annual occurrence from the assessment database. Examples are forest fires, slope failures, tornados, accidents of a nature that alter the stream. Assessment database should be at least one year and up to three years. If the sampling year has less than 20 samples, consecutive years up to three could be combined. The database should be at least 20 separate measurements, at least five days apart. Statistically, six months of sampling, five days apart would yield 36 measurements in one year. Subtracting for flood flows any larger than one-year. Data used for impairment should not be based on storm event monitoring for North Shore streams."	
184			15	Testimony of Curtis Sparks	Poplar River Management Board	Address not provided	Pgs. 88, line 7 "It is unreasonable to set the TSS standard that cannot be met due to natural conditions exhibited in North Shore streams."	See response to comment HE-8-5-8.
185			1	Testimony of Steven Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	Pg. 90, line 7 "The MPCA's proposal is certainly an ambitious attempt to pull together years of studies and reams of monitoring data, much of it coming from our members, into a comprehensive regulatory framework. As with any such effort, however, there are gaps in understanding, and until those gaps are resolved, MPCA's current proposal is not reasonable."	MPCA has a well substantiated and documented package that yields a reasonable set of standards that address nutrient overnerichment of rivers and streams in Minnesota.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
186			2	Testimony of Steven Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	Pg. 90, line 15 "The proposed eutrophication standards are not reasonable because they impermissibly extend the Clean Water Act's reach..... Standard are inextricably linked to beneficial uses. The MPCA's proposal, however, establishes end points that go beyond what is necessary to protect those beneficial uses, which will, in turn, have drastic impacts on the regulated community."	The proposed water quality standard is intended to protect beneficial uses as required by the Clean Water Act.
187			3	Testimony of Steven Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	Pg. 91, line 16 "The proposed standards are not reasonable because the MPCA does not appropriately articulate the interplay of these standards with existing efforts to address impaired waters through total maximum daily loads, or TMDLs."	MPCA has made linkages as appropriate with the lake eutrophication TMDL process.
188			4	Testimony of Steven Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	Pg. 92 line 3 "Once these in-stream standards are adopted, how will that affect TMDLs that currently in place and being implemented. Will this, in effect, require those TMDLs to be reopened and the years of work and expense put into compliance thrown out the window because new criteria are now applicable?"	See response to comment HE-8-10-5.

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189			5	Testimony of Steven Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	Pg. 92, line 10 "While MESERB supports and continues to strongly support the linkage of nutrients with response variables, the use of biochemical oxygen demand, or BOD, dissolved oxygen flux and periphyte in chlorophyll-A as response variables raises a host of issues around the MPCA's impact analyses."	Comment is declarative. No response required. BOD and diel DO flux are addressed in Attachment IV.
190			6	Testimony of Steven Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	Pg. 92, line 18 "MESERB is disappointed that Book 2 of the SONAR, in particular, appears to give short shrift to the cost impacts for greater Minnesota communities and their rate payers."	MPCA included cost estimates for varying sizes of facilities.
191			7	Testimony of Steven Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	Pg. 93, line 4 "MESERB evaluated the MPCA's preliminary cost estimates against a sample of treatment facilities of various sizes on the assumption that the then-proposed standards would be adopted as end-of-pipe effluent limits...... MESERB's analysis makes clear that even when taking into account the myriad of variables that come into estimating compliance costs, the low-cost estimates being provided by the MPCA are not realistic..... MESERB believes that the MPCA's cost estimates are too low by roughly a factor of three, and this information needs to be shared honestly with the public."	MPCA will consider additional cost information if provided with enough specificity to assign costs to treatment technologies. The comment does not offer a level of specific information with which analysis can be conducted.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
192			8	Testimony of Steven Nyhus	MESERB	Flaherty and Hood, 525 Park St. Suite, 470, St. Paul, MN 55103	Pg. 94, line 17 "Although the MPCA is to be commended for its efforts to address nutrients and sediment in rivers and streams, there are still many issues that need to be resolved before these rules may be properly deemed reasonable for adoption."	These rules have been under development for some time. MPCA has worked with individual commenters, including MESERB, at various points in the process to address issues that were raised (examples included on pages 101-105 in SONAR Book 2).
193			1	Testimony of John Hall	Minnesota Environmental Science and Economic Review Board (MESERB)		Pg. 100, line 16 - paraphrased " ...In this situation, all streams are considered identical, and they claim there is no need to distinguish between the two."	Comment is declarative. No response required.
194			2	Testimony of John Hall	Minnesota Environmental Science and Economic Review Board (MESERB)	Address not provided	Pg, 100 , line 18 "They asserted they used the best scientific information, including EPA stressor response guidance document in the analyses.	Comment is declarative. No response required.
195			3	Testimony of John Hall	MESRB	Address not provided	Pg. 100, line 21 and finally, that there wasn't any real difference between state's approach and what EPA would have said is required."	MPCA has used techniques cited in EPA guidance (Exhibit EU-20). Lester Yuan, principal author of EPA guidance, stated that the Agency has put together a coherent rationale for nutrient criteria and that analyses do not have to explicitly follow guidance in order to be scientifically defensible.(Exhibit EU-44). EPA Region 5 and technical reviewers for HQ indicate criteria are scientifically defensible.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
196			4	Testimony of John Hall	MESRB	Address not provided	Pg. 101, line 14 "This is what the EPA said about using statistics to create tease criteria. I quote: "Statistical methods in the guidance require careful consideration of confounding variables before being used as predictive tools. Without such information, nutrient criteria developed using bivariate methods -- that means regressions -- may be highly inaccurate."…. "The underlying causal model must be correct. Habitat condition is a crucial consideration in this regard; i.e., light, for example, canopy, hydrology, grazers, velocity, sediment type,"… that's not adequately addressed in the guidance. Which guidance? The guidance before this one, the same guidance that was used to develop these kind of documents."	MPCA believes it has taken these factors into account and discuss them in the various technical support documents. As these factors relate to periphyton, the Agency has discussed them in the SONAR Book II and Exhibit EU-1.
197			5	Testimony of John Hall	MESRB	Address not provided	Pg. 102, line 6 "Changepoint analysis was a huge issue in that SAB review because I had never seen anybody use it before to try to claim that, just because a changepoint exists, you've actually predicted the right relationship to the nutrients."	Comment is declarative. No response required
198			6	Testimony of John Hall	MESRB		Pg. 102, line 11. "The statement on changepoint from the SAB was the use of changepoint analysis must be associated with biological significance. Such breakpoints do not necessarily have any biological significance, nor will they necessarily be related to designated uses." So in essence, they fairly thoroughly trashed changepoint."	MPCA considered the biological significance of shifts in the biological metrics along the continuum of phosphorus concentrations. The SAB provides cautions in the use of changepoint -- the Agency does not agree they "trashed" the use of this statistical technique. MPCA also used quantile regression as a basis for identifying thresholds and these combined techniques provided thresholds that were used as the basis for the final proposed criteria. In addition, these biological analyses were supported by other lines of evidence as recommended by the SAB report (Exhibit EU-20).

	A	B	C	D	E	F	G	H
1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
199			7	Testimony of John Hall	MESRB		Pg. 102, line 18 "When the stressor response document came out, it supported the use of simplified regressions. You can use them with a caveat: You can use them if enough information is available to address confounding factors. Quote, "Many confounding factors must be considered in estimating the effects of nitrogen, phosphorus on measures of aquatic life in streams; e.g., macroinvertebrate index or fish. Pg. 103, line 9 looking on SONAR on page 51.... Could the staff please tell me where in the -- any of the support documents that you have that you confirmed that phosphorus was actually the cause of the reduced number of sensitive individuals presented in this graph? Does that analysis exist anywhere in the reference documents?"	Pollution sensitive fish were but one of several biological metrics tested (Table 7, SONAR Book 2). The conceptual diagram (Figure 3, SONAR Book 2) provided the conceptual basis for the linkages and the statistical analysis that followed affirmed those linkages and ultimately the role of phosphorus.

	A	B	C	D	E	F	G	H
1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
200			8	Testimony of John Hall	MESRB	Address not provided	Pg. 102,line 18 "When the stressor response document came out, it supported the use of simplified regressions. You can use them with a caveat: You can use them if enough information is available to address confounding factors. Quote, "Many confounding factors must be considered in estimating the effects of nitrogen, phosphorus on measures of aquatic life in streams; e.g., macroinvertebrate index or fish. Pg. 103, line 9 looking on SONAR on page 51.... Could the staff please tell me where in the -- any of the support documents that you have that you confirmed that phosphorus was actually the cause of the reduced number of sensitive individuals presented in this graph? Does that analysis exist anywhere in the reference documents?"	The MPCA addressed these confounding factors using several methods. First, a review of the literature which includes many decades of research documents the well established impacts of nutrients on biological communities (see EU-1 pp. 3-7). In fact these relationships have also been supported by commenters to this rule. Second, EU-1 - Fig 9 demonstrates that although there is a relationship between total phosphorus and total suspended solids and habitat (as measured by the Minnesota Stream Habitat Assessment tool [MSHA]), there are many streams that lack these stressors but still have elevated concentrations of total phosphorus. Despite this, MPCA did not observe streams with high concentrations of total phosphorus with healthy biological communities. This indicates that in the absence of these other stressors, phosphorus is still negatively impacting the biological communities. Finally, the use of quantile regression minimizes the effect of covarying stressors. This method fits the outside of the data plot and thereby is fitting the response of the biological community to the stressor of interest. A more detailed description of this can be found in EU-1 p. 26.
201			9	Testimony of John Hall	MESRB	Address not provided	Pg. 105, line 24 "Is Counsel implying that E -- a letter from EPA pre-determines whether or not somebody actually carried out the assessments that are contained in EPA's guidance document that it said it needed? Are you saying that that verifies it was all done?"	See response at pg. 106, line 5. EPA Region 5 and Headquarters will determine if Minnesota's proposed rule meets the requirements of the Clean Water Act with respect to addressing the impact of nutrients and eutrophication on streams and rivers. Based on the EPA Region 5 submittal Jan 7, 2014 (HE-8-3) "Based on expert comment in total and our (EPA R5) independent review of the proposal, Region 5's preliminary evaluation is that the technical components of Minnesota's proposed eutrophication standards, under peer review for rivers and streams, appear to be scientifically defensible."

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
202			10	Testimony of John Hall	MESRB	Address not provided	Pg. 108, line 24 "So you've indicated that an analysis wasn't done to show that phosphorus actually caused You're not -- you're not implying that phosphorus is a toxic; are you?"	See response at pg. 109, line 4.
203			11	Testimony of John Hall	MESRB	Address not provided	Pg. 110, line 9 "Would you concur with that observation, that where you have high phosphorus in an agricultural area, you probably have a number of other things occurring also, like this pesticide application is high in suspended solids; right? That goes along with the high phosphorus; yes?"	See response at pg. 110, line 15. The analysis in EU-1 Fig. 9 demonstrates that these stressors do not always covary. Furthermore, the negative impacts of nutrient enrichment on biological communities are well documented.
204			12	Testimony of John Hall	MESRB	Address not provided	Pg. 111. Line 9 "Is there anywhere in the SONAR or in the backup documentation that I would find the *Confounding* Factors Analysis, the likes of which that are described in the 2010 Stress Response Guidance Document?"	See response at pg. 111, line 17 . See also response to Testimony of John Hall, comment 8.
205			13	Testimony of John Hall	MESRB	Address not provided	Pg. 113, line 12 "The BOD and diurnal DO flux is certainly not a direct relationship at all, and it's affected by many other factors that have nothing to do with nutrients."	That is correct. Just as chl-a is impacted by a number of factors, so are BOD and DO Flux. That is the reason the MPCA has combined these response variables with the phosphorus criteria to yield the river eutrophication standard. This ensures that systems that do not exhibit elevated chl-a, BOD, or DO flux (indicators of stress to biological communities) will not be listed as impaired.
206			14	Testimony of John Hall	MESRB	Address not provided	Pg. 115, line 2 "Does the PCA disagree that these other factors in addition to chlorophyll-A can affect the BOD 5 test result? (list of factors identified previously)."	MPCA acknowledges those factors contribute to BOD; however they also are sources of phosphorus that lead to increased algal growth (Chl-a).

	A	B	C	D	E	F	G	H
1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
207			15	Testimony of John Hall	MESRB	Address not provided	Page 116, line 16 "Is there anywhere in your analysis of the -- if the SONAR or in any other support document that assessed how and where these factors affect BOD test results that you're going to use as an indicator of nutrient impairment?"	MPCA recognizes these factors may influence BOD_5 or diel flux measurements and the assessment process can consider these factors at specific sites as needed. However, the use of BOD_5 and diel DO flux, as used in development of and as a part of Minnesota's river eutrophication standards, is reasonable and is well supported in Exhibit EU-1, SONAR Book II and Attachment IV. Each measure provides a basis for describing the response of streams to excess phosphorus, as depicted in the conceptual model (Figure 3, SONAR Book 2). USEPA has raised no major issues as to the application of these two variables in our analysis or as response criteria in Minnesota's proposed river eutrophication standard.
208			16	Testimony of John Hall	MESRB	Address not provided	Pg. 117 line 10 "There is nothing in this administrative record that even remotely addresses how these parameters affect BOD test results."	Comment is declarative. No response required.
209			17	Testimony of John Hall	MESRB	Address not provided	Pg. 119, line 7 "So I'm wondering if the PCA can tell me, one, do they disagree that these are things that can affect DO flux; and two, did you assess these anywhere in your -- in choosing the criteria you did?"	See response to testimony of John Hall, comment 14.
210			18	Testimony of John Hall	MESRB	Address not provided	Pg. 120, line 19 "Can you name a single treatise put out any by expert on nutrient control that says BOD is a proper response variable for addressing nutrients?"	A paper by Mallin, et al. 2006; (Exhibit EU-40) "Factors contributing to hypoxia in rivers, lakes and streams" makes a strong case for use of BOD_5 and notes direct stimulation of heterotrophic microbial flora by anthropogenic nutrient loading and its contribution to BOD_5. They also note "an advantage of using BOD_5 in limnological and estuarine assessments is that the standard method is easily performed, repeatable, and widely recognized geographically and across disciplines."

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
211			19	Testimony of John Hall	MESRB	Address not provided	Pg. 122, line 25 "On that question of microbial growth, do you have any data -- because I couldn't find it in your -- in your SONAR or any of the backup documents -- that showed where you had a major increase in microbes without a change in plant growth occurring, and then that caused these adverse effects."	Various articles cited in Exhibit EU-1, e.g. Smith, et al. 2006 and Walker et al. 2006 speak to this issue. In the SONAR Book 2, Mallin et al. (20066: Exhibit EU-40) addresses this as well. EPA (2010: Exhibit EU-20) alludes to the role of microbes.
212			20	Testimony of John Hall	MESRB	Address not provided	Pg. 128, line 8 "Does the PCA agree that the wadeable streams, the smaller streams have a lesser chlorophyll-A response to phosphorus than the larger streams?"	In most instances, yes.
213			21	Testimony of John Hall	MESRB	Address not provided	Pg. 129, line 1 "The standards need to be revised such that we have two sets of standards; one for the big rivers, which have a certain response, and the other for the smaller streams that have a different response. And the importance of that is highlighted by this very critical document from page 84 on the SONAR. That's the graph -- that was the graph of..."	It is reasonable to apply the same standards to wadeable and nonwadeable streams because they can both have the characteristics that are needed to grow large amounts of algae. The main difference is that nonwadeable streams are more likely to have the right conditions to grow algae compared to wadeable streams. In Minnesota there are wadeable streams that will be negatively impacted by nutrients levels above the proposed standard and the MPCA deems it necessary to have this tool to protect these streams.
214				Testimony of John Hall	MESRB	Address not provided	"The phosphorus number versus the concentrations of phosphorus measured in-stream...pg. 129, line 25. The point is if you apply that phosphorus number derived for large rivers to small streams, you will predict impairments that, in fact, do not exist, and you will predict a lot of impairments that don't exist."	See response to John Hall testimony comment 21. In addition this statement is incorrect because the standard includes both nutrient criteria and response criteria. If a wadeable stream does not exhibit elevated response criteria (i.e., BOD, DO Flux, or Chl-a) it will not be listed as impaired.

	A	B	C	D	E	F	G	H
1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
215			22	Testimony of John Hall	MESRB	Address not provided	Pg.130, line 5 "Relatively speaking, are there more small streams in this state or large streams in terms of -- pick any metric; stream miles, stream -- which are there more of?"	See response on pg. 130 line 10.
216			23	Testimony of John Hall	MESRB	Address not provided	Pg. 130, line 25 "So we would suggest that the data are presently insufficient to show and clearly show you shouldn't regulate small streams the same way for phosphorus as large streams would be regulated, and as I mentioned earlier, that's also why the issue of DO flux and BOD is also so important; because the BOD on a small stream is more likely highly influenced by local land use patterns or a little wastewater discharge or septic tanks or things like that, which I don't think is a nutrient issue, but whereas the BOD in the larger streams, that's not so much of an effect."	See response to John Hall testimony comment 21. MESERB has expressed concern with the possible misuse or misapplication of BOD_5 as a part of the river eutrophication standard. As with all monitoring data, MPCA uses professional judgement on sample collection, data interpretation and standards implementation. For example, monitoring conducted by MPCA staff or funded by MPCAis conducted to insure that representative monitoring sites are selected (e.g. for river eutrophication evaluations, sites will not be selected immediately downstream of a WWTF outfall, where it may be possible to have high TP and high BOD_5 that is not a function of river's response to TP). Likewise, in the assessment phase, professional judgment groups review site information to assure that sample collection methods and site selection were appropriate for the river reach (AUID) that is being assessed for compliance with the standard. These considerations are applied to both small and large streams.

	A	B	C	D	E	F	G	H
1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
217			24	Testimony of John Hall	MESRB	Address not provided	Pg. 133, line 1 "Those data (*EU-1 figure one on page 128*) indicated there wasn't really a good correlation between the amount of phosphorus and the amount of periphyton growing in the stream..... line 12 So periphyton don't take much phosphorus to grow pretty robustly....line 21 So what's limiting the periphyton is light or habitat...pg. 134, line 1 If the periphyton number is mainly a light or habitat-limited circumstance, why would we call it the eutrophication criteria? Because it's not being triggered by the excess nutrients, it's being triggered by somebody taking the trees down along the stream, and then a light can hit the stream....pg. 134, line 9... are you thinking that people have to get phosphorus below 20 micrograms in order to control periphyton?"	See response on pg. 134, line 12. The way MPCA proposed it is as a numeric translator as explained in the SONAR (Book 2, page 28-32). When and where it's exceeded, that's where the stressor ID process comes in, is to more fully understand why there are such excessive amounts of periphyton in those areas. Nutrients do contribute, however, there are the other factors, and that's what the stressor ID process would go into to look at what alternatives, what really seems to be controlling it in that stream reach and what the alternatives might be for its control.
218			25	Testimony of John Hall	MESRB		Pg. 136, line 8 "I guess the suggestion we all end up making on the periphyton is we kind of move them out of what I'll call a eutrophication category and maybe create something else....line 23... So if we can figure out a way to avoid that confusion on the application of the periphyton criteria, I think that would be helpful."	MPCA believes it has explained how the numeric translator for excess periphyton will be assessed and implemented. However, further details will be included when implementation guidance is developed in concert with stressor ID staff.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
219			26	Testimony of John Hall	MESRB		Pg. 138, line 9 "So number one, the BOD test on its face tells you don't use it to predict a stream impact unless you know all these other factors. ...it's that same type of approach that one would need to use if you really thought BOD was a reasonable variable to use. But I would point out that, in fact, it is not. There is a simple reason. I don't -- I don't want to put this badly, but I'll just state it plainly. This is a fairly large oops error in what was presented."	BOD has been a part of our overall analysis and river eutrophication standards development since the initial EPA-funded monitoring of 1999-2000, as reflected in the peer-reviewed journal article based on that work (Exhibit EU-4). BOD has been an important part of our river eutrophication monitoring and further analysis appears in the EPA-funded reports in Exhibits EU-2 and -3. BOD has been included with our draft criteria dating back to the 2009 draft that is referenced in Attachment III. At no point has EPA (nor the technical reviewers employed by EPA to review the 2009 draft) questioned its inclusion as one of the response criteria in our proposed standard.
220			27	Testimony of John Hall	MESRB		Pg. 140 , line 5 "So the BOD test was actually the same thing again, but by turning the lights off completely. I mean, algae don't exist in the dark. You wouldn't be able to grow them, interestingly enough; right?... line 17...So this BOD test parameter is not what you thought it was. It is actually something completely different."	Exhibits EU-40 and EU-52a discuss importance of BOD_5 as an important measure when assessing eutrophication impacts. BOD_5 and sestonic Chl-a are highly correlated as demonstrated in Exhibit EU-1 (Figure 26, page 49). Cohen (1990; Attachment VI), in his experiments to assess the role of algae in biochemical oxygen demand, also found that BOD increased linearly with chlorophyll-a concentration. Based on his experiments, he noted "it is reasonable to suggest that the algae died early in the incubation and the oxygen was depleted by bacterial depletion of algae biomass." Hence, while algal respiration does contribute initially to oxygen demand in the BOD test, bacterial decomposition was deemed more important.
221			28	Testimony of John Hall	MESRB	Address not provided	Pg. 140 line 20 "Might also point out that you picked a BOD level that's below the limits of detection -- or at the limits of detection. That probably was not a hot idea, either, but really, the test doesn't measure what you need, and you don't need it."	This statement is absolutely incorrect. A check on MDH (Minnesota Department of Health, MPCA's contract lab) reporting limits indicates they have long had a 0.5 mg/L report limit and there are abundant ambient river BOD_5 data in STORET.
222			29	Testimony of John Hall	MESRB	Address not provided	Pg. 142, line 3 "Are you trying to say BOD is toxic to daughters?"	See response at pg. 142, line 10

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
223			30	Testimony of John Hall	MESRB	Address not provided	Pg. 143, line 7 "Is it accurate that the degree to which BOD will affect DO is a function of the specific physical characteristics of the stream? I mean, it's not the same effect in all the streams. Small and large; right, Steve?... pg. 143, l line 17 guess our suggestion at the end of this is we suggest really move off of the BOD concept. It doesn't really help matters any. It certainly confounds which streams might be impaired.....pg. 144, line 4 We don't want our criteria to point us in the wrong direction. We want our criteria to point us to the place where problems really are. So that's one of the reasons we're suggesting let's just -- let's just move off the BOD point. It's got some issues."	The use of BOD_5, as used in development of and as a part of Minnesota's river eutrophication standards, is reasonable and is well supported in Exhibit EU-1 and SONAR Book 2. Combined with Chl-a and DO flux it provides a basis for describing the response of streams to excess phosphorus, as depicted in the conceptual model (Figure 3, SONAR Book 2). USEPA has raised no major issues as to the application of BOD_5 or DO flux in our analysis or as response criteria in Minnesota's proposed river eutrophication standard.
224			31	Testimony of John Hall	MESRB	Address not provided	Pg. 145, line 12 "Does the State have a metric for the number of sensitive or percentage of sensitive fish you'd expect to have in a stream so I know whether or not something's good or bad?"	There is no one specific goal, there will be different goals for different streams.
225			32	Testimony of John Hall	MESRB	Address not provided	Pg. 146, line 6 "Looking at this chart (reference to SONAR (Book 2)pg. 49) , how could I possibly know that it was DO flux above a 5 milligram flux that caused the low level?.... pg. 146, line 15 How do we know DO flux caused that as opposed to that you had a higher DO flux at a place where the habitat just wasn't as good? Do we have data that could tell us that we know it was the DO flux?"	Habitat data could be taken into account as a part of the "professional judgment" aspect of the assessment process, which is outside the scope of this rulemaking.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
226			33	Testimony of John Hall	MESRB	Address not provided	Pg. 147, line 9 "DO flux is not irrelevant, but it needs to be tied to something. Usually, it's tied to causing a low DO to occur. The State has a DO standard. It has a minimum DO that can exist, and the reason that minimum DO was set was to protect fish, and that DO standard does not indicate, nor, in fact, do I know of any DO standard in the country that has a DO flux component, in and of itself, even if the minimum DO was fine...pg. 147, line 24 However, I'm not aware of any accepted -- and certainly, the EPA hasn't changed the DO criteria to update it to say the mere existence of a flux is an impairment; it's tied to something."	The use of diel DO flux or DO range, for purposes of assessing the response of rivers to excess nutrients has precedent with Montana (Exhibit EU-52a & b), Ohio (Exhibit EU-25,-26), and New Jersey (NJDEP 2010; *2010 Integrated Water Quality Monitoring and Assessment Methods).* It is either used as a part of nutrient-related water quality standards or is an integral aspect of river nutrient standards assessment and implementation. In addition, the MPCA has documented a strong relationship between DO diel DO flux and biological responses (Exhibit EU-1 and Section 1 of Attachment IV).
227			34	Testimony of John Hall	MESRB	Address not provided	Pg. 148, line 5 "If you want to keep it (DO Flux) in there, you can probably put it in like as a secondary indicator, but not something that phosphorus plus DO flux means automatic nutrient impairment."	DO flux is a valuable indicator of response to nutrient overenrichment. It has been a part of Minnesota's proposed criteria since the 2009 draft criteria that were submitted for EPA review. At no point has EPA questioned the inclusion of this variable. This variable is used by other states as well (e.g. Ohio, Montana, and New Jersey) for the same or similar purpose.
228			35	Testimony of John Hall	MESRB	Address not provided	Pg. 149, line 18 "The numbers that were chosen by the PCA, the DO fluxes that they picked are so low they're just about background in the various streams. They don't really reflect an impairment level."	The proposed DO Flux criteria are in line with strong, negative impacts that are demonstrated by analyses using Minnesota data. Attachment IV firmly establishes this along with all previous evidence in Exhibit EU-1.

	A	B	C	D	E	F	G	H
1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
229			36	Testimony of John Hall	MESRB	Address not provided	Pg. 152, line 7 (in reference to SONAR graphs) "So we've got a phosphorus that's not controlling the periphyton, we've got a periphyton that's acceptable, and we've got a DO flux of 8 that's telling me I've got a phosphorus eutrophication problem. Boy, I got the answers all bolloxed up because we knew phosphorus wasn't the control, we thought periphyton was acceptable at that level based on the invertebrate data we have at streams, and this is telling me I've got an impairment.... I would suggest we go back and rethink this flux thing."	See Attachment IV, Section 1.
230			37	Testimony of John Hall	MESRB	Address not provided	Pg. 153, line 13 "So we're going to suggest, I think the way to work back out of this, at least in our view, is to go to a large stream/small stream and get rid of the BOD issue and then rethink DO flux."	MPCA has established that is reasonable to have the proposed standards applied to both small and large streams. As the Aggency has stated, most sampling for the purpose of assessing stream eutrophication will be conducted on medium to large streams. When and if small streams are monitored for this purpose, the standards may still be applied. In practice, we believe that the field measurement of diel DO flux will be a valuable and reasonable basis for assessing response of streams to excess phosphorus. In contrast, MPCA does not believe that BOD5 will be measured routinely as a part of river eutrophication assessments. In part, because of the cost of laboratory analysis and because the measurement of sestonic Chl-a will be favored in most studies designed for assessment of river eutrophication. However, it is reasonable to retain BOD5 as a response criterion and as a part of the overall river eutrophication standard as instances may arise where it can be used as an additional basis for assessing a river's response to excess phosphorus.

	A	B	C	D	E	F	G	H
1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
231			38	Testimony of John Hall	MESRB	Address not provided	Pg. 153, line 20 "The data for Red River North was taken out of those data sets when the regressions were done; correct?...pg. 155, line 11... If the Red River doesn't act like the other large wadeable rivers, wouldn't it be appropriate to not apply those numeric criteria to the Red River North?...pg. 155, line 21... it would seem particularly inappropriate to apply a criteria to a stream that you know didn't really fit based on your own analysis."	The proposed standards may reasoanbly be applied to the Red River. Should the assessment process indicate otherwise, the possibility of site specifc standards remains.
232			1	Testimony of Tim Sundby	Carver County	Address not provided	Pg. 157, line 4 "My understanding is that those were --you're using that (the Omernik 1987 report) as the only boundaries, and there are bedrock, there's no errors within any of that report whatsoever across the whole United States. My contention is that, yes, there has been an error. Your report, the next year, was that you did catch that error, and it is shown in all the -- in the tables, I believe Tables 1 through 5 within -- within your documentation. And instead of kind of going through there and fixing it, it was stated that the North Central Hardwood Forest is a transitional area. So it kind of envelopes that disparity between that Typical Area 1 and Typical Area 1 through -- 2 through 7 within the North Central Hardwood Forest.....pg. 157, line 19... My understanding is that this error was caught by you guys, and this is our chance to change that error and move that Typical Area 1 from North Central Hardwood Forest to the Western Cornbelt Plains Ecoregion, and that's my comment."	The Fandrei et al. report (HE-13) demonstrated that there is variability in land use composition among the typical areas in the NCHF ecoregion. This does not imply there was an error in the initial EPA mapping. It has always been recognized that the NCHF ecoregion is transitional between the forested NLF ecoregion to the north and the highly agricultural WCBP to the south.

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1	Date Received	Comment #	Sub-comment	Name	Affiliation	Address	Summary of Comment	Response
233			1	Testimony of Paul Nelson	Scott County	Scott Co. Natural Resources, 200 Fourth Ave. W., Shakopee, MN 55379-1220	Pg. 158, line 17 "I did want to point out that in one of the documents -- and I'm sorry, I don't know the reference number, the Regionalization of Minnesota Rivers for Application of Nutrient Criteria, WQS618 Table 1-A. If you look at the numbers that are given for percentiles and quartile ranges from work that Steve did back in 1993, that you'll see for many of the ecoregions in there, the 75th percentile, let alone the 90th percentile, exceeds the standards that are being proposed.....pg. 159,line 5... this could bring into question whether they're actually regulating natural background, and . . .That is not allowed in my understanding of either state or federal regulation because the streams that are in Table 1-A are minimally impaired."	See Exhibit EU-5, Table 1a, page 12. The streams being referenced from Exhibit EU-30 were termed minimally-impacted based on a lack of wastewater treatment plants immediately above the monitoring site. There would still be other nonpoint (anthropogenic) sources of nutrients and sediments reflected in these data.

Attachment I - Spreadsheet Summary of Comments and MPCA Responses

Attachment II - Response to Comments on Regionalization (River Nutrient Region map)

Attachment III - MPCA Response to Hearing Exhibit HE-8-8c, issues raised by MCEA/ JoAnn Burkholder

Attachment IV - MPCA Response to Comments Relating to Analysis Issues (Supplemental Analyses to Address Questions Regarding Dissolved Oxygen Flux, Reference Condition Analysis, Midpoint Quantile Regression Analysis, and the Derivation of Proposed Criteria from Multiple Lines of Evidence)

Attachment V - *"Minnesota's Approach to Lake Nutrient Criteria Development"* Heiskary S. and Wilson B. (Lake and Reservoir Management 24:282-297, 2008)

Attachment VI - *"Biochemical Oxygen Demand and Algae: Fractionation of Phytoplankton and Nonphytoplankton Respiration in a Large River"* Cohen R. (Water Resources Research, Vol. 26, No. 4, pp. 671-678)

The Response includes the MPCA's detailed response to comments that were available for review during the public comment period and post-hearing comment period, November 18, 2013, through January 28, 2014, (HE-8-1 to HE-8-11) and to oral statements made at the public hearings on January 8, 2014. Attachment I is a spreadsheet compilation of the comments received during that same period. In Attachment I, the MPCA excerpted or paraphrased the written comments received during the hearing, the oral testimony presented at the hearing, and comments that were filed by January 27, 2014, and available for MPCA review during the post-hearing comment period. Where a comment number is cited in this memorandum, it refers to the comment number assigned in Attachment I (e.g. HE-8-X).

This memorandum contains summary responses to comments as they relate to issues identified by multiple commenters or, in a few instances, a specific response to a specific comment. Where the MPCA agrees with a comment requesting a change to rule, a proposal for specific changes to the proposed rule language is included. Some comments may not be addressed in detail in this memorandum, but the MPCA has responded to every comment in the spreadsheet provided in Attachment I. Comments the MPCA considered to be out of scope for this rulemaking are not specifically addressed in this memorandum, but are noted in Agency responses in Attachment I.

II. General response

After diligent consideration of comments made on the proposed rule, and as required by Minn. Stat. § § 14.131, 14.14, subd. 2, and 14.15, subd. 4, and Minn. Rules § 1400.2100, the Agency has shown the rule as proposed with the additional definition noted below is needed and is reasonable as demonstrated by and affirmatively shown by facts presented by the Agency on the hearing record.

III. MPCA proposed change to rule in response to comments received

Prior to the hearing, the United State Environmental Protection Agency (EPA) submitted a comment (HE-8-1 EPA) recommending the addition of a new definition for "Eutrophication Standard" in Minn. Rules § 7050.0150, subp. 4. The MPCA agrees that adding such a definition is appropriate and will propose the adoption of the following definition at Minn. Rules § 7050.0150, subp. 4, item H and the subsequent re-lettering of the definitions that follow (subject to approval by the Revisor of Statutes.)

> *H. "Eutrophication standard" means the combination of indicators of enrichment and indicators of response as described in Subp. 5. The indicators upon which the eutrophication standard for specific water bodies are based are as provided under subparts 5a to 5c.*

The addition of a definition for "Eutrophication standard" is not substantially different from the proposed rule because, as required by Minn. Stat. § 14.05 subd. 2:

- the definition is within the scope of the matter announced in the notice of hearing;
- the definition is a direct and logical outgrowth of comments submitted in response to the notice of hearing;
- the notice of hearing provided fair notice to persons interested in and affected by the rule amendments that changes to definitions or additional definitions would be part of the rule in question;
- the addition of the definition does not change in any way the group of persons who will be affected by the rule;
- the subject matter of the definition is the same as the subject matter contained in the notice of hearing; and
- the definition does not alter the effects of the rule proposed in the hearing notice.

IV. Response to general categories of comments

This section provides summary responses to general categories of comments identified by multiple commenters. As previously noted, Attachment I provides detailed Agency staff responses to each individual comment. The general categories of comments are:

A. Comments supporting adoption of the proposed amendments;
B. Comments regarding proposed River Nutrient Regions (RNRs);
C. Comments regarding the reasonableness of the scientific analysis supporting the River Eutrophication standards;
D. Comments regarding the need for the total suspended solids (TSS) standard;
E. Comments indicating the underlying analysis of the TSS standard is wrong;
F. Comments regarding the need for a specific TSS standard for North Shore/2A streams;
G. Comments regarding the economic analysis provided for the rule amendments; and
H. Comments regarding implementation issues and the need for further implementation guidance.

A. Comments supporting adoption of the proposed amendments

Comments HE-8-3 (EPA), HE-8-9 (Everett), and HE-8-11 (EPA) generally support the adoption of the TSS and Eutrophication standards and generally support the defensibility of the scientific analysis underlying the standards and the use of River Nutrient Regions. Comment HE-8-8 (MCEA) provided a general statement of support for the adoption of standards to address nutrient enrichment; and comment HE-8-4 (Scott) provided a statement of support for the adoption of a TSS standard. Comment HE-8-10 (Worthington) also provided a statement of general support for the need to address nutrient enrichment of Minnesota's waters.

B. Comments regarding proposed River Nutrient Regions (RNRs)

Comments HE-8-2 (Carver) and HE-8-4 (Scott) and the testimony provided at the hearing by Tim Sundby and Paul Nelson identify specific concerns with the MPCA's proposal to adopt the River Nutrient Regions (RNRs) established in *Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria,* as adopted by reference into the definition of "Ecoregion" in Minn. R. pt. 7050.0150, subp. 4. The comments, while not denying the value of a classification system based on large scale regions, maintain that the proposed classification system is in error regarding the classification of the southern lobe of the Central Region and that the underlying analysis for establishing the Central River Nutrient Region is not reasonable.

The adoption of the River Nutrient Regions established in *Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria* as the ecoregions for regional water quality standards is reasonable because:

- The ecoregion approach is recommended by U.S. EPA as a means for regionalizing nutrient water quality standards.
- Use and development of the RNRs were based on ecoregions established by the EPA.
- The approach used by the EPA for defining ecoregions grew out of an effort to classify streams for more effective water quality management.
- The ecoregion framework is the basis for regionalizing Minnesota's lake eutrophication standards, and the use of ecoregions in the proposed water quality standards provides for a consistent regional framework for streams and lakes.

The classification system used to define the River Nutrient Regions is not in error regarding the classification of the southern lobe of the Central Region. The area in question (Typical Area 1) is defined by Omernik (HE-12) as an area considered to be "most typical" of the North Central Hardwood Forest ecoregion. The ecoregion within which Typical Area 1 lies in the North Central Hardwood Forest.

A more detailed response to comments on this issue is provided in Attachment II.

C. Comments regarding the reasonableness of the scientific analysis supporting the River Eutrophication standards

Comments HE-8-8 (MCEA) and the hearing testimony of John Hall identify specific concerns regarding the reasonableness of the scientific analysis supporting the river eutrophication water quality standards. While the perspective of these commenters differs, the concerns relate primarily to: reference condition analysis; response variables (five-day biochemical oxygen demand (BOD_5) and dissolved oxygen (DO) flux); choice of statistical methods; and derivation of the proposed river eutrophication standards from multiple lines of evidence. Attachment I contains individualized responses to each comment.

The need for the river eutrophication water quality standards is established in SONAR Book 2, pgs. 19-33. The need for the river eutrophication standards is not questioned and is supported by comments.

SONAR Book 2 and supporting exhibits provide detailed descriptions of the data used, analysis undertaken and choices made by MPCA in developing, and establishing the reasonableness of, the proposed river eutrophication water quality standard.

The structure of the river eutrophication water quality standard, which includes a cause variable and three alternative response variables has not been questioned by EPA. Rather, EPA has consistently supported Minnesota's development and use of BOD_5 and DO flux as response variables and submitted comments in support of the statistical analysis used and choice of response variable thresholds.

MCEA's comments support the use of the three response variables and choice of statistical approaches used (i.e. quantile regression and changepoint), but question the choice of cause and response variable thresholds (i.e. upper breakpoint and midpoint) derived from these approaches. MCEA states that the threshold choice is unreasonable because it will sacrifice many fish species and individuals. The development of river eutrophication criteria supports attainment of the Clean Water Act (CWA) interim goal. This goal is defined in the CWA as: "wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water (33 U.S.C § 1251(a)(2))." The interim goal of the CWA does not require that all waters must meet goals equivalent to natural or pristine conditions. The statistical methods used by the MPCA were focused on setting minimum goals that support attainment of the CWA interim goal. This was accomplished by the use of metrics that are sensitive to eutrophication and by identifying thresholds that are consistent with attainment of the CWA interim goal. These relationships and the location of thresholds determined using Minnesota data closely correspond to the location of defensible thresholds derived from stressor-response relationships in Stevenson, et al. (2008) (see Figure 2 in Stevenson, et al. (2008), as cited in SONAR Book 2, pg. 133). These thresholds are consistent with the protection of "fishable/swimmable" goals as defined by the interim goal of the CWA, and therefore, support Minnesota's aquatic life use goals.

Many of MCEA's concerns were previously expressed during the rule development period. These concerns were included in an evaluation by Dr. JoAnn Burkholder submitted to MPCA on September 12, 2012. MPCA carefully considered the concerns and responded at that time by meeting with MCEA to discuss the issues and relating responses to their concerns. Subsequently, MPCA re-analyzed data, made revisions to proposed criteria, and clarified supporting documents. Attachment III to this Response contains the 2012 MCEA evaluation and MPCA's 2012 response to these issues.

Unlike EPA and MCEA, John Hall questioned the validity of MPCA's changepoint and quantile regression analyses. As support, Mr.Hall referred to cautions articulated by the Science Advisory Board (SAB) regarding changepoint analysis. MPCA considered the biological significance of shifts in the biological metrics along the continuum of phosphorus concentrations. The SAB report (SONAR Book 2 Exhibit EU-20) provides cautions in the use of changepoint, but indicates that it can be used as part of the water quality standard development process. MPCA also used quantile regression as a basis for identifying thresholds. These combined techniques provided thresholds that were used in a multiple lines of evidence approach to develop the final proposed criteria. The changepoint and quantile regression biological analyses were supported by other lines of evidence as recommended by the SAB report (Exhibit EU-20).

As a direct response to Mr. Hall's comments on the relationship between biological responses and diel dissolved oxygen (DO) flux, MPCA undertook additional analysis during the post-hearing comment period. This additional analysis incorporated updated datasets with increased sample sizes. The additional analysis confirmed the initial analysis showing a negative impact of increased DO flux on biological communities. Attachment IV to this Response contains the details of this additional analysis.

In many of his comments, Mr. Hall attempts to minimize, and thereby discredit, the connection between the cause variable and the chosen response variables in the river eutrophication water quality standard. MPCA agrees that just as the Chl-a response variable is impacted by a number of factors other than phosphorus, so are BOD_5 and DO Flux. That is the primary reason the MPCA has combined these response variables with the phosphorus criteria to yield the proposed river eutrophication standard. This combination of cause and response variables ensures systems that exhibit only elevated chl-a, BOD, or DO flux (indicators of stress to biological communities) without elevated phosphorus will lead to further analysis. Attachment V provides additional literature MPCA staff relied upon in developing the proposed eutrophication standard. Attachment VI is provided in response to Mr. Hall's comments on the use of BOD_5 as a response variable.

MPCA has meticulously considered concerns relating to the underlying analysis and derivation of the proposed river eutrophication standards. The underlying analysis and proposed river eutrophication water quality standards are reasonable.

D. Comments regarding the need for the total suspended solids (TSS) standard

One commenter (HE-8-5 Poplar River) supported the elimination of the existing turbidity standard but also argued there is no need to adopt a TSS standard. The MPCA has provided a three point discussion of the need for the TSS in SONAR Book 3, pgs. 5-6. The TSS standard is needed because:

- Suspended sediments adversely affect the Class 2 aquatic life beneficial use of surface waters;
- Since the adoption of turbidity water quality standards in 1967, scientific advances in water assessment and water quality understanding support a transition from a statewide turbidity standard to a regionalized TSS standard; and
- EPA supports the transition from turbidity to TSS.

The commenter asserts that because EPA has not issued a TSS criteria document, Minnesota should not adopt a standard. The Clean Water Act § 303 (33 U.S.C. § 1313) requires states to develop water quality standards. Minnesota Rules ch. 7050 and 7053 include water quality standards for many pollutants adopted as required by the CWA. The adoption of a TSS standard by Minnesota without independent EPA action to adopt a TSS criteria is well within the requirements of the Clean Water Act and EPA guidance. Similarly, Minnesota law (Minn. Stat. § 115.03 subd. 1(c)) grants MPCA the power "to establish and alter such reasonable pollution standards for any waters of the state in relation to the public use to which they are or may be put as it shall deem necessary for the purposes of this chapter and, with respect to the pollution of waters of the state, chapter 116;..." A TSS standard is needed in Minnesota to establish a reasonable standard to protect aquatic life beneficial uses, based on scientific advances allowing reasonable transition from the of the current turbidity standard to a TSS standard.

The commenter further stated that there is no need for a TSS standard because TSS is currently used as an effluent limit in some implementation activities. As required by the Clean Water Act (CWA § 303(c)(2)(B)), water quality standards are developed for the protection of beneficial uses. In the case of the existing turbidity standard and the proposed TSS standard, they are developed for the protection of aquatic life. As stated above, the SONAR Book 3, pgs. 5-6, present the need for a TSS standard including the need to protect aquatic life beneficial uses of surface water. The use of TSS as an effluent limit is immaterial to the promulgation of a TSS water quality standard. There is no contradiction in using TSS as both a water quality standard and an effluent limit.

E. Comments indicating the underlying analysis of the TSS standard is wrong

Two commenters (HE-8-4 Nelson and HE-8-5 Poplar River) challenge several of the data choices in the analysis supporting the TSS water quality standards. The commenters incorrectly characterize several of the data choices, and are incorrect about the impact of other data choices on the analysis. Detailed responses to each assertion by the commenter are included in Attachment I. The proposed TSS standard provides an approach that acknowledges regional differences in TSS generated from the landscape, more complete use of biological effects data, and use of a seasonal and weather-related data. Further technical discussion is found in the SONAR Book 3, pgs. 5–10. The data choices and analysis supporting the TSS water quality standard are reasonable.

F. Comments regarding the need for a specific TSS standard for North Shore/2A streams

One commenter (HE-8-5 Poplar River) identified a need to provide a separate TSS standard for North Shore streams claiming the characteristics of these streams to be significantly different than other Class 2A cold water streams in the state. The current Class 2A Turbidity water quality standard and the proposed Class 2A TSS standard were developed to protect trout and other cold water organisms. The biological analysis underlying the TSS standard applies to important cold water species (e.g., trout, sculpins) which inhabit cold water streams throughout the state. It is reasonable for the proposed rule to include a TSS standard that applies statewide to cold water streams because of the species similarity. Further discussion of effects of suspended solids on trout is found in SONAR Technical Support Document TSS-1.

G. Comments regarding the economic analysis provided for the rule amendments

Comments HE-8-6 (MESERB) and HE-8-10 (Worthington) identify specific concerns regarding the economic analysis provided by MPCA in satisfaction of the requirements of Minn. Stat. § 14.131, for the proposed river eutrophication standards. Comments HE-8-7 (Asphalt Pavement Assoc.) expressed concerns with the economic analysis in relation to both the river eutrophication standards and the TSS standards. The commenters raised similar concerns that: the cost estimates provided were too low; the analysis did not adequately address the specific costs of the proposed standards on all types of wastewater dischargers; and the analysis was flawed because of deficiencies in process or data. Specific responses to each of these commenters concerns are included in Attachment I.

The MPCA developed its economic analysis based on the statutory directive of Minn. Stat. § 14.131 which requires agencies to describe the probable costs to be borne by affected parties "to the extent the agency, through reasonable effort, can ascertain this information." A full accounting of costs and benefits is not anticipated, nor required, to fulfill the requirements of Minn. Stat. § 14.131. The Agency undertook reasonable effort to ascertain the probable costs of complying with the proposed rule for regulated parties, the agency, local governments, and others affected by the rule. The SONAR describes in detail the data used and the results of the reasonable effort undertaken by the Agency to ascertain the probable costs of complying with the proposed rule for identifiable categories of affected parties. (Book 1, pgs. 23-30; Book 2, pgs. 106-107, and pgs. 112-127, exhibits EU-41a-d and EU-42; Book 3, pgs. 18-25, exhibits TSS-4 and TSS-5.)

Commenters stated that the economic analysis did not consider such factors as cold climate conditions, specific technologies (e.g. membrane filtration), costs other than operation and maintenance, or provide the most current estimates. Commenters did not offer specific alternative cost data for consideration. Exercising reasonable effort, the MPCA conducted a review of cost information available at the time the SONAR was drafted, selected a reasonable cross-representation of the applicable technologies and cost data to consider, and made reasonable assumptions to address a wide range of highly variable factors. The MPCA focused its discussion on the most likely impacts to entities that will bear costs for compliance. The analysis provides information about the costs of the proposed standards for a range of municipal and industrial dischargers and stormwater permittees. It is not possible, nor is it required, to analyze every possible scenario. The data choices and cost analysis are reasonable and meet the reasonable effort requirements of Minn. Stat. § 14.131.

In addition, it is important to note that Federal water quality rules require states to adopt water quality standards based on sound scientific rationale to protect designated beneficial uses (40 C.F.R. § 131.11 (2013)). This federal Clean Water Act requirement is not bounded by economic factors. While economic impact is not a consideration that influences the establishment of the standard, economic impact may play a role in the implementation of the standard when applied to a specific regulated party. This individualized economic impact, however, is not part of establishing the standard.

The MPCA has made a reasonable effort to evaluate the costs of compliance for the proposed river eutrophication and TSS standards. As a general principle, comments about deficiencies or disagreements about the validity of the economic analysis do not affect the fundamental reasonableness of the proposed standards as they relate to the protection of Minnesota waters. Minnesota's Administrative Procedures Act (Minn. Stat. § 14.131) requires consideration of the economic effects of proposed rules "to the extent the agency, through reasonable effort, can ascertain this information." In response to that mandate, the MPCA provided in its SONAR a reasonable assessment of expected costs associated with the proposed water quality standards. As mentioned in the SONAR, actual costs and economic effect of water quality standards are highly variable, given the extreme variety of dischargers, treatment technologies, receiving waters and the numerous permitting, financial and administrative options available to mitigate the costs. The MPCA has provided a reasonable estimate of the expected costs and economic effect of the proposed amendments.

H. Comments regarding implementation issues and the need for further implementation guidance

A number of commenters raised questions about how the proposed water quality standards will affect existing implementation activities such as: Total Maximum Daily Load (TMDL) studies and waste load allocations (HE-8-10); MPCA's water assessment process (HE-8-5); permit and compliance requirements generally and under specific conditions (HE-8-7 and HE-8-8); and policy choices regarding regulated and non-regulated entities (HE-8-10-7).

The MPCA understands the concerns of the regulated and non-regulated communities regarding implementation of significant new water quality standards and their effect on ongoing regulatory programs such as permitting, water assessment and TMDL studies. Adoption of new water quality standards begins the integration of the standards into existing implementation processes. Modification of some implementation processes is generally anticipated with the adoption of a new water quality standard. The SONAR Book 2, pgs. 80-91, addresses, to some degree, anticipated implementation concerns for the river eutrophication standards. However, the development and adoption of the water quality standards is bound only to the protection of beneficial uses of surface water and groundwater and is not limited by implementation concerns. The Clean Water Act requires water quality standards to protect beneficial uses (CWA § 303(c)(2)(B)) without limitation from implementation concerns.

In addition, comments regarding implementation address issues outside of the scope of the rule amendments. As noticed, the scope of the rule amendments is limited to the following aspects:

- Establishment of Class 2 Eutrophication water quality standards for rivers, streams, Mississippi River navigational pools and Lake Pepin;
- Establishment of Class 2 total suspended solids (TSS) water quality standards; and
- Minor "housekeeping" revisions and re-phrasings of supporting rule language for these water quality standard changes.

The scope does not extend to rules governing activities undertaken to implement water quality standards. The policy question of regulating currently unregulated parties is likewise outside the scope of this rulemaking.

V. Conclusion

The MPCA has thoroughly and diligently considered and responded to all comments available for review. The MPCA has demonstrated through the SONAR, the hearing presentation and oral testimony, and responses to comments, that the proposed amendments are needed and reasonable.

Minnesota Pollution Control Agency
Attachment II to Response to Comments Dated January 28, 2014
OAH Docket # 60-2200-30791
Revisor's # 4104

Attachment II. Response to comments on regionalization (River Nutrient Region map)

The following is in consideration of comments received on Tuesday, January 7, 2014 from Mr. Tim Sundby of the Carver County Water Management Organization and Paul Nelson, Scott County and also to comments submitted at the hearing held on January 8, 2014.

These comments are in regards to the MPCA proposing water quality standards for river eutrophication and total suspended solids (TSS) based on River Nutrient Regions (RNR) for Minnesota.

Mr. Sundby contends that an area within and surrounding Carver County, described as part of the Central RNR, be reclassified into the South RNR. The report from Mr. Sundby outlines an alternative approach, referred to as the Rosgen Classification, which uses river geomorphology as a basis for classification. Mr. Nelson requested that some tributaries (and their watersheds) in Scott County that drain to the Minnesota River should be classified as part of the South RNR as opposed to their current Central RNR classification.

In support of the methodology used, in conjunction with the proposed Water Quality Standards (WQS) for river eutrophication and total suspended solids, the MPCA offers the following response:

1. Use and development of the RNRs were based on ecoregions established by the U.S. EPA. This is explained more fully in Exhibit EU-5.
2. Ecoregions were developed by the U.S. EPA based on maps of land surface form, soils, potential natural vegetation and land use (Omernik 1987; HE-12). The approach used for defining ecoregions grew out of an effort to classify streams for more effective water quality management.
3. The ecoregion approach <u>is recommended by U.S. EPA</u> as a means for regionalizing nutrient water quality standards (Exhibits EU-10, EU-11, EU-12, EU-14 and HE-8-11).
4. The ecoregion framework was used as basis for regionalizing Minnesota's lake eutrophication standards. Heiskary and Wilson (2008; Attachment V to the MPCA's Response to Comments) provide a summary of the development of those standards and application of the ecoregion framework. The use of ecoregions in the proposed river eutrophication standards provides for a consistent regional framework for streams and lakes.
5. A report authored by Fandrei, Heiskary, and McCollor (1988; HE-13) was referenced in Mr. Sundby's submittal. The purpose of the Fandrei et al. (1988) report was to help develop the ecoregion concepts for application in Minnesota. This included characterizing water resources, and the physical, hydrological and topographical attributes of each ecoregion to aid in the management of stream and lake water quality in Minnesota.
6. Reference was made to the "most typical areas" in Mr. Sundby's submittal. Omernik (HE-12) defines these areas as the "most typical portions of each ecoregion and are those areas sharing all of the characteristics that typify that ecoregion." Typical Area 1, is one such area that is considered to be "most typical" of the North Central Hardwood Forest ecoregion.
7. Based on the RNR approach Carver County and surrounding areas are characterized properly.
8. Based on the RNR approach tributaries in Scott County were mapped appropriately.
9. The Rosgen Classification is good for purposes of management and implementation of actions on the landscape but not as a basis for classifying streams for water quality standards development.

In conclusion, the MPCA stands by the approach of using RNR in setting WQS for river eutrophication and total suspended solids in rivers and streams across the state. Further support of this approach is available in the associated rulemaking documents and any further comments on this topic will be included in MPCA's overall response to comments.

Attachment III
MPCA Response to Hearing Exhibit HE-8-8c
Issues Raised by Minnesota Center for Environmental Advocacy (MCEA)/Joann Burkholder

The document entered into the hearing record as HE-8-8c was previously submitted to MPCA on September 14, 2012. MPCA staff reviewed all comments and assembled preliminary responses to MCEA on October 2, 2012 (appended below). The October 2, 2012 response document will serve as the MPCA's response to the comments made in HE-8-8c. MPCA responses are in red. MPCA staff shared these responses orally at a meeting with MCEA (JoAnn Burkholder, Kris Sigford, and Michael Schmidt) on November 15, 2012. MPCA staff: Steve Heiskary, Will Bouchard, Mark Tomasek, Steve Weiss, and Howard Markus were in attendance at that meeting. Meeting notes and a Power Point presentation from the November 15, 2012 meeting are available if needed.

Subsequent to that meeting, MPCA revised the 2010 version of the draft Technical Support Document, taking into account many of MCES concerns. This included re-analysis of data, some revision to the proposed criteria and various edits to the text to provide improved clarity in presentation of the information. That revision was finalized on January, 2013 (Exhibit EU-1). The foreword from EU-1, excerpted below, explained why revisions were made to the 2010 document and provides some sense of the extent of revisions.

Foreword

This technical support document for Minnesota's proposed river eutrophication criteria has undergone several revisions as a result of internal and external review, refinements in data analysis, and related factors. This revision of the 2010 draft document is a product of comments from and discussion with USEPA reviewers, Minnesota Center for Environmental Advocacy, and other reviewers. Minor modifications are included to provide greater clarity in descriptions of data sets, statistical analyses, and justifications for the proposed criteria. Slight adjustments to the proposed criteria have been made as a part of this revision. Criteria, as proposed in this revision, will be used to develop rule language and further supported in the Statement of Need and Reasonableness (SONAR) that is developed in support of the rulemaking.

The document below serves as MPCA's response to HE-8-8c. The MPCA is addressing the MCEA comments dated January 6, 2014 (HE-8-8a) in its Response to Comments and Attachment I.

Evaluation of MPCA Draft River Eutrophication Criteria –
Initial MPCA responses to Dr. Burkholder comments
October 2, 2012

Review conducted by Dr. JoAnn Burkholder
for the
Minnesota Center for Environmental Advocacy (MCEA)
12 September 2012

Overall Assessment

The United States Environmental Protection Agency (U.S. EPA) mandated that states adopt ambient nutrient criteria by the end of 2003 (National Strategy for the Development of Regional Nutrient Criteria, June 1998, p. iv). U.S. EPA provided a series of nutrient criteria guidance documents and recommended criteria for nutrients (causal variables total phosphorus, TP, and total nitrogen, TN) in lakes and streams within designated nutrient ecoregions. States were given the option of using the numeric nutrient criteria recommended by EPA, or developing their own scientifically defensible numeric criteria that protect the designated uses of surface waters.

U.S. EPA (2000a-d, 2001) has used stressor-response relationships to derive nutrient criteria mainly by identifying threshold concentrations at which large changes in biological metrics (the response variable, suspended algal chlorophyll *a* and others) occur because of increasing nutrient concentrations. U.S. EPA (2000a) and various states have recognized that biological thresholds are valuable for setting nutrient criteria because there is a direct link between biological responses and protection of designated uses for aquatic life.

The Minnesota Pollution Control Agency (Heiskary et al. 2010, hereafter referred to as MPCA unless otherwise noted) has presented draft eutrophication criteria as summer means ($n \geq 6$ samples per summer for at least two summers) for Minnesota rivers (flowing waters, from small streams to large rivers) within three "river nutrient ecoregions" (RNRs) that it designated. The proposed criteria include the causal variable TP and the response variables corrected chlorophyll *a* (chl*a*), five-day biochemical oxygen demand (BOD_5), and dissolved oxygen (DO) flux (that is, the maximum change in DO concentration over a diel or 24-hour period). The criteria are based mostly on stressor-response relationships that have been documented between nutrients and certain measures of biological integrity (fish and macroinvertebrate metrics) from an array of fish and macroinvertebrate metrics. There is strong precedent for use of biological data to support stressor-response criteria derivation, and setting protective river nutrient criteria would be a major step forward in restoring many Minnesota rivers from the detrimental impacts of eutrophication.

MPCA describes having used a weight of evidence approach "to develop river nutrient criteria that are protective of aquatic life and recreation goals." However, this analysis finds that the criteria developed are *not* protective due to MPCA's use of eight scientifically unsound steps, each of which *elevates* the numeric criteria and *weakens* protection of the designated uses of warm water rivers in Minnesota. Together, these policy decisions substantially *increase* the levels of nutrients that would be deemed acceptable. They also are much higher than the scientifically supported thresholds identified by additive quantile regression smoothing analysis (AQRS) (Wang et al. 2007, Brenden et al. 2008), a sound statistical procedure that MPCA applied and then ignored.

MPCA (p.ii) lists seven external U.S. EPA Region V and U.S. EPA Headquarters-related reviewers (Thompson, Heaton, Miltner, Selvaratnam, Dodds, Stevenson, and Paul). Readers mistakenly infer from the writing that these renowned experts favorably reviewed the present draft of this document (MPCA 2010). They did not. Copies of the reviews, and confirmation by reviewer Dr. J. Stevenson (personal communication to Dr. J. Burkholder, March 2012), show that these reviewers saw only the MPCA (2009) version of the document. The earlier version did not contain some of the non-science-based steps now included in MPCA (2010), such as MPCA's use of "interpolated midpoints" rather than the threshold values identified by AQRS.

[January 24, 2014 clarifying note: *Reviews were conducted on the 2009 draft TSD. MPCA sent this draft to EPA Region 5 for their preliminary review and comment. Region 5, in turn, asked if Region 5 technical assistance group members (R5 states) and EPA Headquarters could review this draft as well. MPCA agreed to this. The reviews from the three external reviewers: Stevenson, Paul, and Dodds were done at the behest of EPA HQ. Their reviews and our response to their comments have been included as Book II Exhibits EU-22 (a,b), 23 (a,b), and 24 (a,b). These responses were sent to EPA R5, who in turn forwarded them to EPA HQ (we do not know if they were forwarded from EPA HQ to the technical reviewers). MPCA also provided responses to the R5 state reviewers via EPA Region 5. MPCA believes these were forwarded to the states. The collective comments of the external reviewers and R5 state reviewers were considered in the revised 2010 draft TSD.*]

These draft criteria will fail to protect the designated uses of Minnesota's rivers from degradation by nutrient pollution. The following comments in support of that overall evaluation are organized into three main sections:

- *Summary* – The eight steps that MPCA used to weaken protection of the designated uses of warm water rivers in Minnesota are summarized, and other major concerns about the draft eutrophication criteria are briefly outlined;
- *The eight steps* – Detailed comments are presented about each of the steps that weaken protection of the state's rivers from nutrient pollution; and
- *Other major concerns* – Other issues about numeric nutrient criteria for Minnesota rivers are explained in detail.

Summary: Eight Steps Followed by MPCA that Weaken Protection of Minnesota Streams, and Other Major Concerns

The Eight Steps

Minnesota Pollution Control Agency
Attachment III to Response to Comments Dated January 28, 2014
OAH Docket # 60-2200-30791
Revisor's # 4104

1) <u>The data are very poorly described</u> – The description of the datasets used to develop the draft criteria lacks clarity and includes many inconsistencies and missing information.

This can be improved. Previous documents provide more details. Have begun work on this. Improved descriptions relative to Tables 2-4, number of observations for Tables 10 and 12. Much of this was described in greater detail in previous publications and it was not our intent to repeat all that information in this TSD. However some information has been added to provide the reader with more information on the sites monitored, frequency of monitoring and related information.

We can work on clarifying some of these issues. However, some of the discrepancies are the result of the comprehensive approach and the diverse datasets used to develop these criteria. This included the use of data that were not collected specifically to support development of nutrient criteria. As a result, data were aggregated using a number of methods. Depending on how data were aggregated (e.g., by site, by AUID, etc.), different datasets were used for the analyses in this study. For example, data used to develop the water chemistry relationships used data collected specifically to support the development of river nutrient criteria (i.e., River Nutrient study). This dataset included multiple parameters collected concurrently and included multiple collections during the summer season which made it useful for understanding the relationships between these parameters. The STORET dataset is larger than the River Nutrient dataset and it includes many of the same measures, but the STORET dataset include data that were not collected concurrently and data that were not collected systematically during the summer season. These characteristics could result in error which gives us less confidence in the STORET data despite the larger sample size. However, with that being said, the relationships between River Nutrient and STORET water chemistry measures were similar. In addition, there was not a need to regionalize this analysis as it was assumed that these water chemistry relationships were similar across Minnesota. The biological data were associated with STORET water chemistry data using AUIDs. This aggregating procedure would be expected to increase the error in these relationships. However, the analyses used the outside of these wedge data which minimizes the effect of this error. This is valid because the effects of stressors on relatively long-lived biological communities such as fish and macroinvertebrates, will persist even when the stressor is no longer present.

2) <u>The draft eutrophication criteria are not based on reference (minimally disturbed) conditions, compromising threshold analysis and development of protective criteria</u> – Reference or minimally disturbed conditions were not used to develop the draft criteria. Based on the 25th percentile of STORET data, in each RNR - even in the relatively pristine north/northeast part of the state – few of the streams that were used to develop the draft criteria were minimally impacted (North RNR: 3 of 9 streams; Central RNR: 4 of 16 streams; South RNR: 5 of 18 streams). This step minimizes use of high-quality streams throughout the analyses, and skews the analysis toward poorer water quality as "acceptable" in supporting already-compromised biota while also not protecting the biota of higher-quality streams. It additionally results in datasets for which threshold conditions cannot be identified (as acknowledged by MPCA, pp.63-64), precisely because the higher-quality

> streams are mostly missing from comparison. For the South RNR, remarkably, MPCA also ignores the heavy agricultural land use and describes the streams impacted by agriculture as simply reflecting natural and unknown causes.

We did not emphasize the reference approach. This is but one approach offered by EPA. Comparisons were made with regional data summaries. This could be expanded and comparisons clarified.

There is data from a set of sites minimally impacted by point sources from McCollor & Heiskary (1993) used in the multiple lines of evidence (Table 17c). The TP values from this analysis (25th percentiles) compare favorably with the draft criteria. In general, the draft criteria are more protective in the South region and less protective in the Central and Northern regions than the minimally impacted reference condition. However this is only one line of evidence and since it does not necessary relate directly to protection of aquatic life use goals, it is not given the most weight. The critique recommends following EPA's guidance for using quantiles of the reference condition (75th percentile) or from all stream (25th percentile). First if we consider using the 25th percentile of all streams, it requires the *a priori* assumption that 75% of streams are impaired. We don't feel comfortable making such an arbitrary decision because it assumes a similar impairment rate across the state. In addition, it is not directly related to attainment of ALU goals. So we can eliminate the use of a 25th percentile of all sites as a useful or appropriate method in setting nutrient criteria. The second and more useful method is using a set of reference sites to inform or set criteria. However, this approach also has limitations. Specifically, there are few sites in the Southern region that we can consider to be reference so calculation of the 75th percentile would be based on a relatively small number of streams and therefore prone to greater error. In the Northern region the opposite is true. We likely have sufficient numbers of reference sites, but then we need to consider how the reference condition in this region relates to attainment of ALU goals. The reference approach In the North is overly protective of Minnesota's ALU goals and the results are uncertain for the Southern region. Therefore it is not appropriate to rely too heavily on the reference condition although it can be informative. This does not mean that streams that are performing better than these goals should or can be degraded down to the proposed criteria. Other rules such as antidegradation and the forthcoming TALU rule will backstop these high quality streams.

The criticism is made that the River Nutrient dataset does not include enough "reference" streams. The purpose of the River Nutrient study was to sample sites across the state to capture a range of conditions and not to document statewide nutrient patterns. Furthermore the River Nutrient dataset was not used in the reference dataset as that would not have been appropriate due to the sample size and the site selection process. River Nutrient provides and understanding of how nutrients and their associated stressors are related. This information supported conceptual linkages and development for measures that could not be directly tied to biological responses.

The evaluation also asks what the STORET data was not used with the biological data. The STORET data provided a dataset that permitted direct comparison of BOD to the biological communities. A good TP-Biological dataset was available using the biomonitoring dataset and a similar analysis using the STORET data would have been as strong due to smaller size of the STORET dataset and the data aggregation method that was used to link the biological data to the STORET chemistry data.

Chlorophyll-a was not assessed due to the relatively small size of the STORET dataset after the biological data was linked and the ability to relate biology responses to chlorophyll levels using models.

A review of the STORET data is provided in the evaluation. The most important line of evidence provided is the 25th percentile of TP, chla, and BOD all sites for each region. As discussed above this approach is of little value. It assumes *a priori* that 75% of streams are impaired and is not tied to attainment of ALU goals. It would really only be of value if this was the only data available for setting nutrient criteria. The evaluation treats this line of evidence independently of the other forms of evidence that USEPA nutrient criteria guidance manual (EPA 2000) and subsequent reports recommend for developing nutrient criteria.

3) A non-protective, scientifically invalid statistical approach, "midpoint interpolation," is used to develop excessive draft eutrophication criteria – The draft criteria are much too high to protect Minnesota rivers from nutrient pollution because they are based on a scientifically invalid statistical approach of "midpoint interpolation" to determine stressor thresholds. If allowed, this step would eliminate many sensitive biota that are valued ecosystem components (see MPCA, Table 7). This step also makes it possible for MPCA to assert, falsely, that the thresholds derived from AQRS are comparable to the thresholds derived from other analyses (see below), as "multiple lines of evidence" in support of the draft criteria.

This is critical. The approach seems reasonable, given the lack of actual biocriteria at the time of derivation. A later comparison with BCG in July 2012 may be of value in helping to demonstrate further that this approach is valid and has support.

The justification of the "midpoint interpolation" approach is described in the report. The critique suggests that a more appropriate threshold is the upper breakpoint. However this breakpoint can be interpreted as a background condition, which is not in line with Minnesota's aquatic life goals or the Clean Water Act (CWA) interim goal. These goals do allow for some loss of sensitive species although they ultimately protect the overall structure and function of these communities. Conversely, the lower breakpoint is interpreted as the point at which the biology is no longer declining and has essentially reached the bottom of the response. Again this is clearly not in line with Minnesota's aquatic life goals or the Clean Water Act interim goal. Although we agree that the midpoint is somewhat arbitrary, we have performed additional analyses that indicate that this point is protective of Minnesota's aquatic life use goals as measured by biological criteria (see below; Steve- We could put this in an appendix in the TSD). We also want to be clear that although Minnesota's aquatic life use goals represent the minimum allowable condition, it is not a pollute down to threshold. Streams that perform better than aquatic life use goals will need to be protected through anti-degradation and Tiered Aquatic Life Uses (TALU). Under a TALU framework, we will perform additional analyses to determine if more stringent nutrient criteria are needed to protect high quality or Exceptional waters. This approach will allow Minnesota to protect these waters without setting overly protective background concentration standards across the state that are unattainable currently and not in line with the CWA.

Comparison of IBI biocriteria with nutrient criteria metrics

To determine if the metrics used to develop Minnesota's river nutrient criteria are correlated with attainment of biological criteria, an analysis was performed to compare metric thresholds with thresholds calculated at three different probabilities of attaining the biocriteria. The metric thresholds were calculated by interpolating metric values from the candidate eutrophication stressor thresholds (i.e., total phosphorus, chlorophyll a, BOD, DO flux; e.g., Figure 1). These analyses were made using 75th percentile additive quantile regression smoothing (AQRS) fits. In Figure 1, the phosphorus candidate threshold was 154 µg/L and the interpolated metric value was 38 taxa.

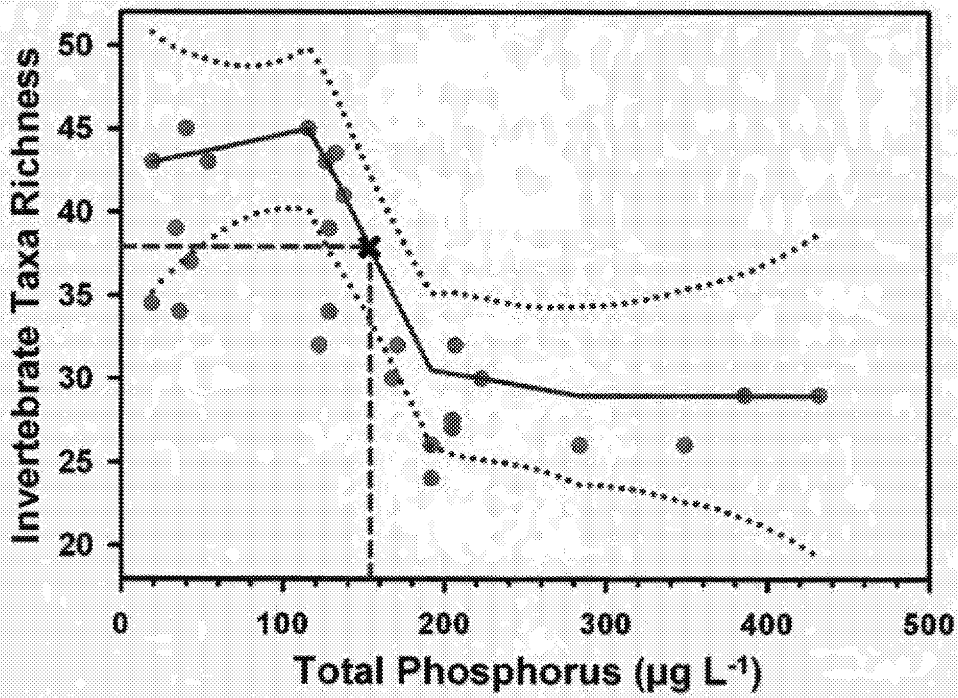


Figure 1: Example of interpolation of the metric value associated with phosphorus candidate threshold determined using the midpoint between breakpoints.

Loess quantile regression fits were made to determine the metric scores at different probabilities of attainment of the biocriteria[1]. For example with the % intolerant fish individuals, when the proportion of these fish is 3% or higher there is a 50% probability that the biocriteria will be attained (see Figure 2 and Table 1). Likewise when the proportion of intolerant fish individuals is ≥9% or ≥16% there is a 75% and 90% probability, respectively, of attaining the biocriteria. These relationships do not indicate causality, but are rather an illustration of how these different biological metrics relate. The metric scores for each probability and each metric are in Table 1.

[1] The Normalized IBI is calculated by subtracting the IBI score be the biocriteria. Therefore negative values are IBIs that scored below the thresholds and *vice versa* (FIBI = Fish IBI, MIBI = Macroinvertebrate IBI)

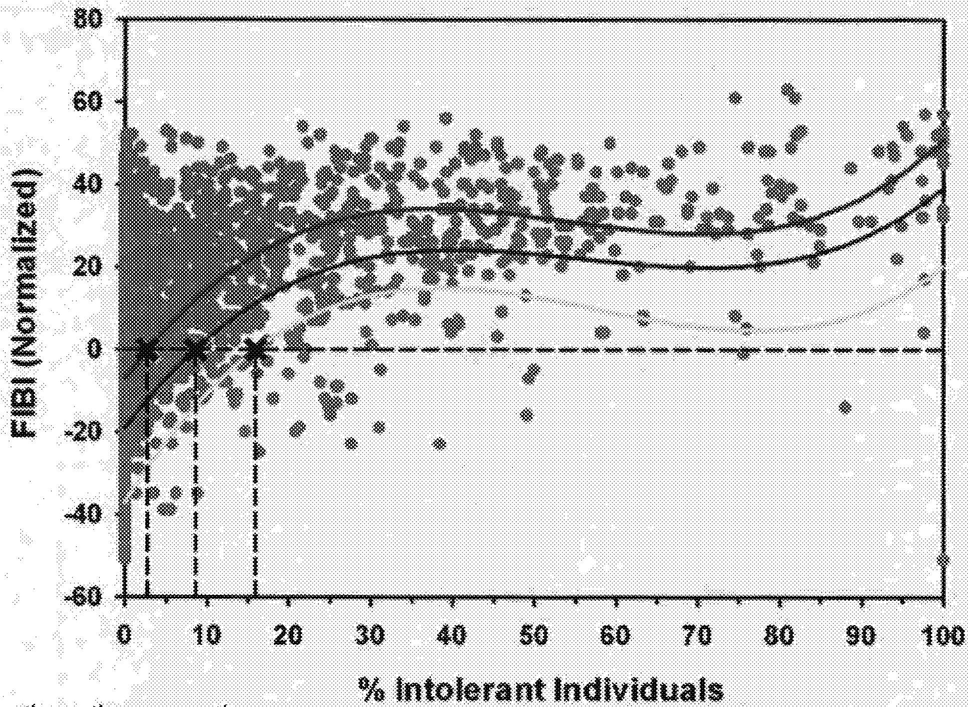


Figure 2: 50th, 25th, and 10th percentile loess quantile regressions fit to normalized IBI and biological metric datasets. The red line is the 50th percentile, the blue line the 25th percentile and the yellow line the 10 percentile.

Table 1: Metric thresholds at three different probabilities of attaining the biocriteria determined using loess quantile regression. A "-" indicates that no threshold could be determined.

Assemblage	Metric	Probability 50%	75%	90%
Fish	%Darter	5	81	83
Fish	%Insectivores	28	-	-
Fish	%Intolerant	3	9	16
Fish	%Piscivores	3	14	-
Fish	%Sensitive	7	17	31
Fish	%Simple Lithophils	19	70	-
Fish	%Tolerant	72	30	9
Fish	Taxa Richness	9	28	34
Invertebrates	#Collector-Filterer	5	7	9
Invertebrates	#Collector-Gatherer	13	19	-
Invertebrates	#EPT	7	11	15
Invertebrates	#Intolerant	3	6	8
Invertebrates	%Tolerant	76	-	-

Invertebrates	Taxa Richness	39	45	51

A comparison of the two metric threshold methods is in Figure 3. In general the metrics interpolated using the AQRS fits indicated protection of >50%. The 75% probability attainment fell within the distribution of AQRS metric scores for most of the metrics. The same was true at the 90% probability although a few more fell outside the distribution of AQRS metric scores. In some cases AQRS metric scores were well below protection levels (e.g., % Darters and % Simple Lithophils), but these were related to poor IBI-metric relationships.

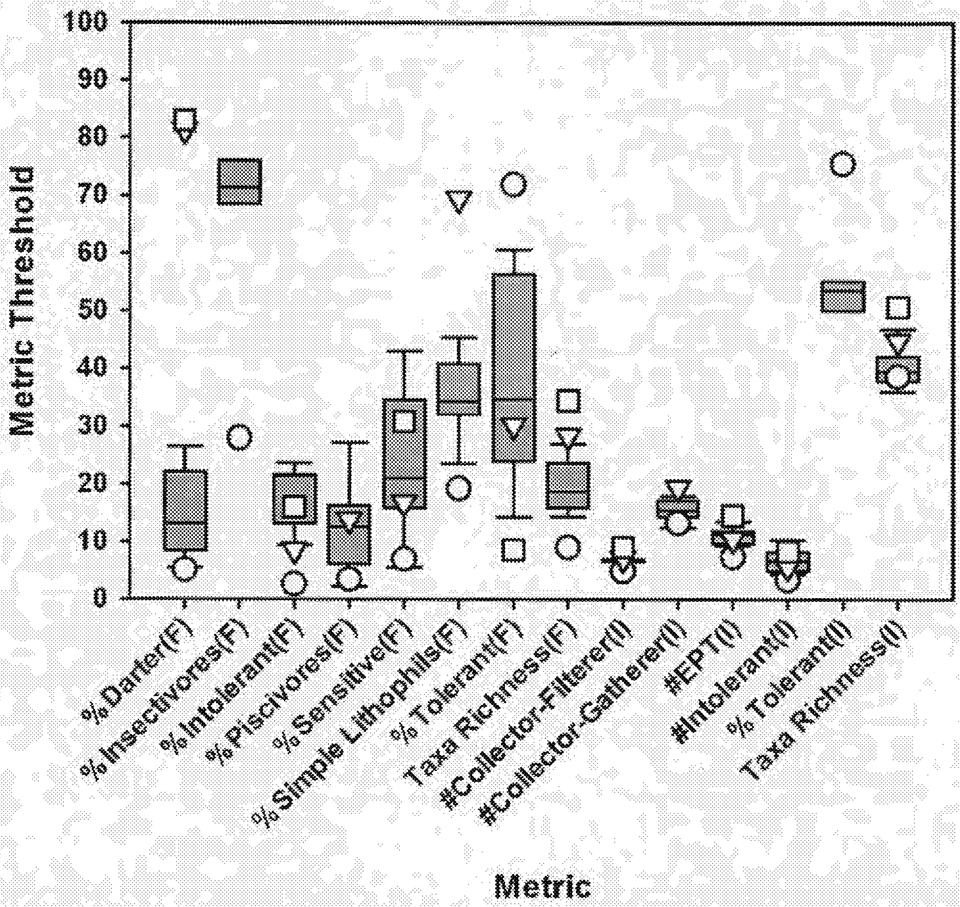
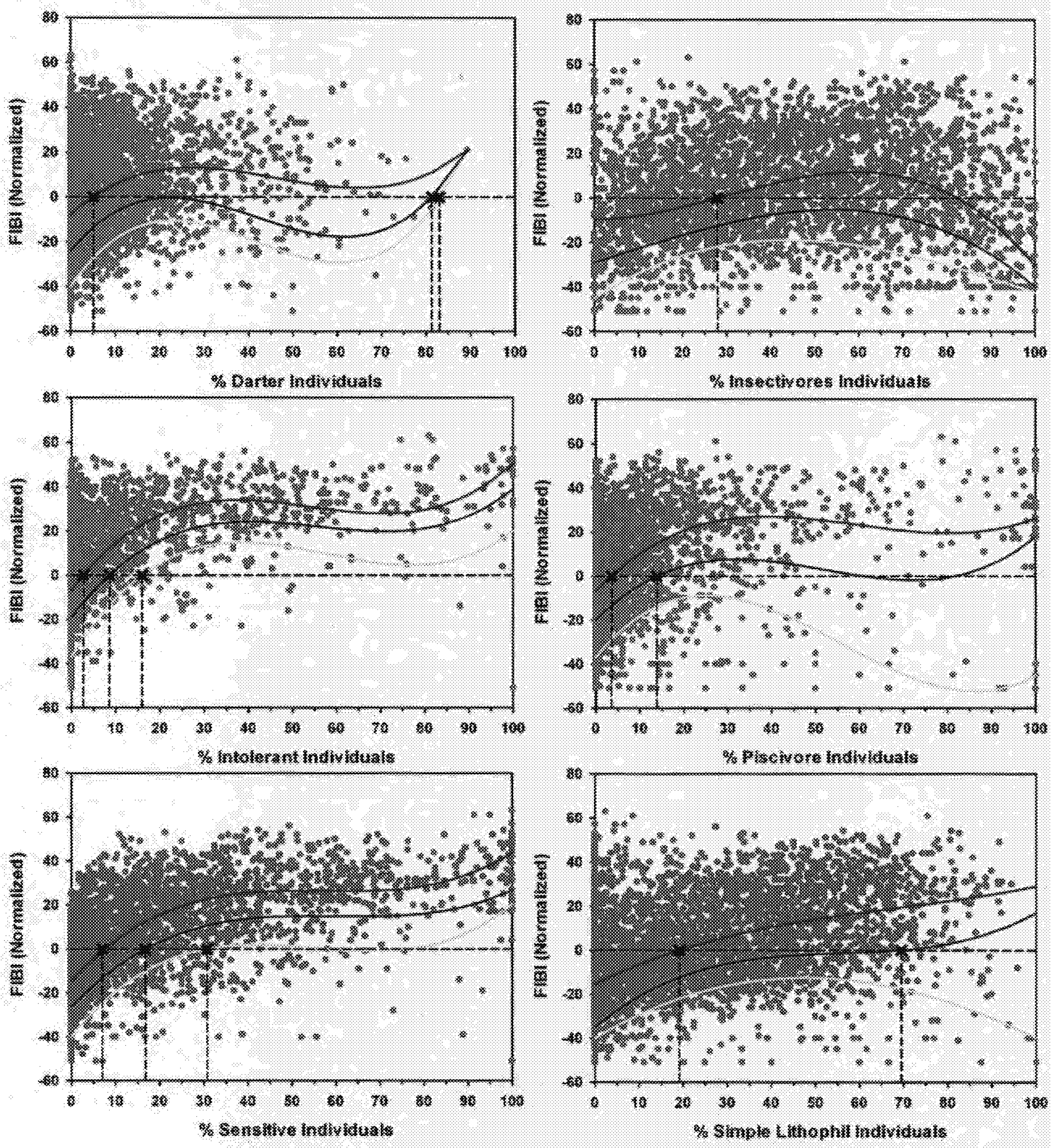
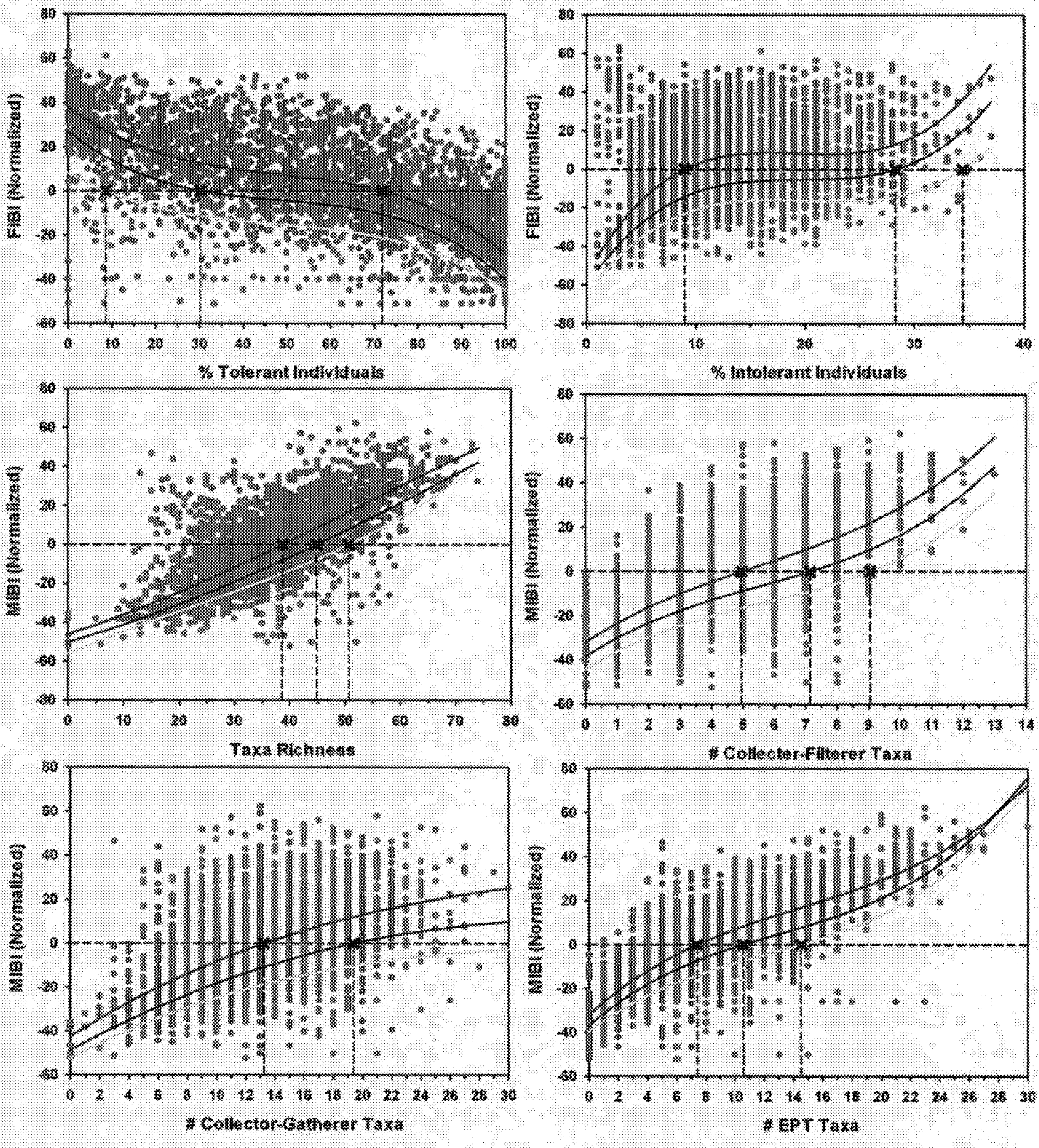


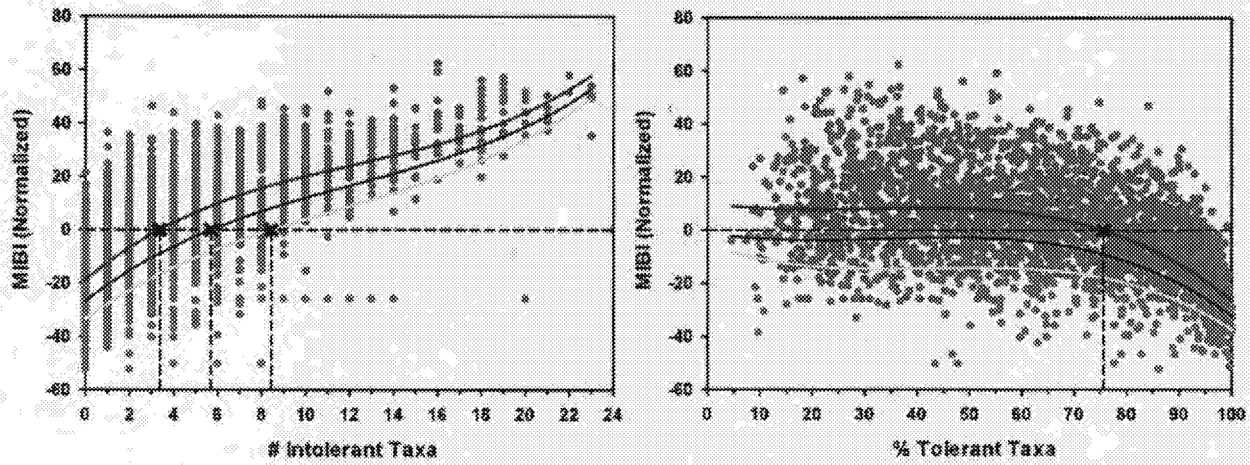
Figure 3: Comparison of metric thresholds determined from interpolating values from the 75th percentile additive quantile regression smoothing (AQRS) fits with eutrophication stressors (total phosphorus, chlorophyll a, BOD, DO flux) and from the relationship between metrics and the IBIs at three different probabilities of attaining the biocriteria. Box plots are the distribution of metric thresholds from multiple 75th percentile AQRS fits with the eutrophication stressors and fish and macroinvertebrate metrics. Symbols indicate the 50% (circle), 75% (triangle), and 90% (square) probabilities of attaining the biocriteria for each metric for fish and macroinvertebrates.

Plots of IBIs versus nutrient criteria metrics

The following plots illustrate the relationship between Minnesota's new IBIs and the biological metrics used to develop Minnesota's nutrient criteria for rivers and streams. All metrics, except % tolerant individuals, have a positive relationship with the IBIs.




FIBI (Normalized)
% Tolerant Individuals
% Intolerant Individuals
MIBI (Normalized)
Taxa Richness
Collecter-Filterer Taxa
Collector-Gatherer Taxa
EPT Taxa



4) The statistical methods and steps used to derive the draft criteria are very poorly explained, and inferior statistical approaches are weighted equally to, or higher than, AQRS in MPCA's "multiple lines of evidence" – The explanation given by MPCA about its statistical analyses is so poorly written that it is often impossible to follow, and the scientific validity of the steps used cannot be assessed. Of three analyses that MPCA used to determine thresholds, changepoint analysis has been shown to be inferior to AQRS to identify thresholds for sub-acute biological responses to stressors. Changepoint analysis yielded much higher thresholds than AQRS, until "midpoint interpolations" were erroneously applied to significantly increase the AQRS thresholds. The serial regression of BOD → chl*a* → TP yielded much higher TP threshold concentrations than the other two analyses. There is no way to assess whether MPCA verified that the error terms were independent (uncorrelated), important because serial regression analysis is confounded if the error terms are correlated, expected for chl*a* and BOD since chl*a* contributes to BOD.

I don't understand the comment that "explanation given by MPCA about its statistical analyses is so poorly written that it is often impossible to follow, and the scientific validity of the steps used cannot be assessed". The critique needs more detail here (I'll look to see if I can find more in the full document) if we are to address this. The methods description for AQRS and changepoint are at least as, if not more, descriptive than that required for a peer reviewed article. AS a result we disagree with Burkholder's criticism and don't see how it can be used to improve the analyses if required.

In regards to the validity of AQRS versus changepoint, I agree that AQRS is a stronger analyses, but not so much so that the results of changepoint analysis should be disregarded. The critique implies that the midpoint interpolation was selected to make the AQRS line up better with the changepoint. Although they do often produce similar threshold concentrations, the selection of the midpoint for interpolation was justified based on other factors (see above).

We agree that there concern about the compounding of error in the serial regression. [This is something that I will look into quantifying. However, we know that there is uncertainty associated with predictions. These systems are all different so the values we have developed will be overprotective for some waters and under protective for others. The response criteria provide some of the flexibility to ensure that that criteria are more appropriate for a given water. As a result, these natural differences are dealt with by these secondary criteria and if necessary site specific criteria can be developed.]

5) <u>MPCA's emphasis on pollution-tolerant biological metrics rather than sensitive metrics results in draft criteria that are much too high to protect sensitive biota from nutrient pollution</u> – In developing the draft eutrophication criteria, MPCA considered fish and macroinvertebrate metrics to be acceptable if most sites were as low as the 25th percentile in biological quality, and emphasized pollution-tolerant metrics rather than sensitive metrics. MPCA also omitted the important synthesis biological index for fish health, IBI scores, from consideration.

I fundamentally disagree with this. Most of the metrics used are "sensitive" metrics. In fact these individual metrics can be more responsive than composite indices such as the IBI which contains metrics that are responsive to a variety of stressors. I did look at DELTs and did not see a nutrient response with this measure.

6) <u>Wadeable and nonwadeable streams are considered together, without scientific basis</u> – Nonwadeable streams generally have much higher suspended algal chl*a* concentrations per unit TP than wadeable streams (see MPCA, p.42, Figures 19 and 20). Smaller, wadeable streams tend to respond to nutrients via periphyton rather than suspended algae (Whitton 1975). MPCA developed its draft eutrophication criteria based almost entirely on data for nonwadeable streams, then "combined" the two stream size classes and applied the same draft criteria to both (p.78, Table 17a). The overall effect is that aberrantly high suspended algal chl*a* concentrations from nonwadeable streams would be evaluated as "acceptable" in wadeable streams at the draft criteria levels of TP. This step by MPCA is not scientifically justified.

The alternative is to exclude small wadeable streams from rulemaking. We recognize the differences between wadeable vs. non-wadeable and hence this is how and why we focused our studies as we did. I think a case was made for combining the information and statistics. Could this be made clearer?

I would like to understand the theory behind the idea that high levels of chla are okay for nonwadeable streams, but not for wadeable streams. Perhaps it is assumed that the biological communities in nonwadeable streams are more tolerant of these stressors? I'm not sure that is the case when you consider the wadeable prairie streams in the south and central regions of the state. Part of the issue is the small sample size of detailed WQ data from the wadeable streams. We had the same problem with biological data for the large rivers which make thresholds hard to estimate. It is possible that with a larger dataset in the future we could reexamine criteria between these size classes. However, I believe the draft criteria are close to what is needed to protect large and small streams.

7) *Total* chlorophyll (Chl-T) is wrongly used by MPCA to develop draft criteria for *corrected* chl*a*, so that much higher living algal biomass is erroneously considered to be acceptable for Minnesota rivers – The draft document uses Chl-T as the metric for living, suspended algal biomass in Spearman Rank correlations analyses to assess correlations among TP, TN, suspended algal biomass, DO flux, various other environmental factors, and all of the major selected biological metrics (Table 13). Chl-T is also used in the threshold analyses (Table 14). MPCA then "suddenly substitutes" corrected chl*a* for Chl-T in setting the draft criteria. All of this is scientifically invalid because pheophytin (the degraded chlorophyll pigment in dead and dying algal cells and plant detritus) is not included in corrected chl*a* measures; only the biomass of living algal cells is included (Wetzel and Likens 2000).

Pheophytin makes up, on average, about 30% of the Chl-T in Minnesota rivers (MPCA, p.19). Therefore, MPCA's use of Chl-T in the analyses, then erroneously "substituting it" as corrected chl*a*, artificially elevates corrected chl*a* by an average of ~30%. In fact, as much as half of a Chl-T measurement can be degraded pigment from dead/dying cells that would not be included in the corrected chl*a* measure of living algal biomass (Heiskary and Markus (2001 - the key reference described by MPCA, p.19; also see Hendey et al. 1987 and Wetzel and Likens 2000). Thus, with this step MPCA "artificially elevates" the living algal biomass that the draft criteria would allow in Minnesota rivers by 30% on average, and even by as much as 50%. These elevated draft chl*a* criteria will not protect the designated uses of Minnesota rivers from nutrient pollution.

We did shift from Chl-T to Chl-a. We did this for consistency with lake eutrophication criteria and to place emphasis on viable Chl-a as is routinely done in eutrophication assessments.
Assume later analysis did use Chl-a (as graphs suggest); if not we may need to repeat those analyses.

8) Reference (minimally impacted) conditions are not compared to the draft criteria and do not support them – MPCA (pp.77-79) errs in its assertion that the draft eutrophication criteria compare favorably with the published literature values for reference or minimally impacted rivers. The major publication (McCollor and Heiskary 1993) used by MPCA to describe minimally impacted conditions and corroborate its draft criteria actually included streams from areas that are heavily influenced by agriculture and/or urbanization, because only point sources were considered as contributors to pollution. Nutrient concentrations typical of true minimally impacted conditions are much lower than reported in McCollor and Heiskary (1993) (see below). MPCA also misquotes the published literature and makes various errors of omission, so that the references claimed to support the draft criteria do not support them.

Have corrected one of references that was drawn directly from another article. Our stream data were not reference, rather they were representative for the region and did not have immediate upstream point source impacts – they were not true, unimpacted reference sites.

The CDF in Appendix Figure I-1 does a good job of demonstrating regional distributions and provides a valid basis for comparison. Other comparisons were drawn from EPA criteria summary documents.

Other Major Concerns

- There are no total nitrogen (TN) criteria – It is now well established that eutrophication in freshwaters across the nation is influenced by nitrogen as well as phosphorus. U.S. EPA has required the states to develop both TP and TN criteria. The draft document presents a weak, unconvincing argument for not developing TN criteria. TN criteria are needed to protect Minnesota streams from degradation by nutrient pollution.

Do not intend to pursue at this time. Will emphasize nitrate-N in future rulemaking.

- There are no criteria that specifically protect high-quality waters - The draft document uses a circular argument to assert, without basis, that the draft criteria will protect rivers with conditions that are better than what the criteria would require.

TALU will provide this if it is supported by data analysis.

- There are no criteria that specifically protect potable supplies, which are prone to toxigenic cyanobacteria outbreaks – Some rivers used for potable supplies in Minnesota are prone to noxious cyanobacteria blooms, including potentially toxic species that can cause disease in humans and beneficial aquatic life.

If deemed necessary, this can be addressed with site specific criteria. It is agreed that protection of water supplies is important; however there is no indication that current finished drinking water, derived from river water sources presents a risk to consumers of the water (from the standpoint of blue-green algal toxins).

- There is no analysis to demonstrate whether/how downstream waters will be protected by the draft criteria – The draft document asserts, without supporting documentation, that the draft criteria will protect downstream waters.

Using MINLEAP model as a basis for inferring standards are protective of lakes, is valid for NLF and NCHF ecoregions as the stream values used are representative of minimally-impacted watersheds. However, that is not the case for WCP so that comparison has been removed. We have made the case for downstream protection in the navigational pool and Pepin documents – based largely on the mechanistic modeling for the Lake Pepin TMDL.

We are now in the process of summarizing stream TP projections from approved and draft lake nutrient TMDLs to see how these "modeled" values compare to the proposed criteria. In any case, if a TMDL required a lower inflow TP – that would effectively "trump" the in-stream criteria.

- Coldwater streams are not covered by the draft criteria – The draft document excludes coldwater rivers from consideration (see p.26).

This will be addressed by TALU.

- The "numeric translator" for periphyton is based on relatively sparse data.

Based on sparse data from Minnesota; however, it is based on a comprehensive literature review and the proposed number seems well supported.

- Compliance is poorly explained – The steps used to assess compliance should be clearly outlined in the draft document.

This is addressed in greater detail in the SONAR. The assessment approach is clearly presented. Monitoring is now underway to allow for assessment once rule promulgation is complete. Approach will emphasize non-wadeable streams; however, waters upstream from identified impaired stream reaches will be considered as part of the overall solution (TMDL).

Attachment IV.
MPCA Response to Comments Relating to Analysis Issues

Supplemental Analyses to Address Questions Regarding Dissolved Oxygen Flux, Reference Condition Analysis, Midpoint Quantile Regression Analysis, and the Derivation of Proposed Criteria from Multiple Lines of Evidence

January 21, 2014

Section 1. Dissolved Oxygen Flux

During the Public Hearing on January 8, 2014, John Hall questioned the relationship between biological responses and diel dissolved oxygen (DO) flux. The analyses the MPCA presented in EU-1 were based on a relatively small dataset (fish = 25 sites, macroinvertebrates = 21 sites) and although some of the patterns were strong the MPCA agrees that additional work could be performed to better resolve these relationships. The original analyses in EU-1 were performed in 2010 and since this time, the MPCA has collected additional DO flux data as a part of our overall river monitoring efforts. The analyses from EU-1 were repeated with this larger dataset to determine if the original results are supported and if DO flux-biology relationships can be better defined.

Updating the dataset increased the sample size for the fish from 25 to 74 sites and for macroinvertebrates from 21 to 61 sites. See EU-1 pp. 26-34 for a description of the methods used to identify thresholds. The number of thresholds that could be identified was increased from 4 to 10 (Tables 1 and 2). The increased sample size clarified some of the relationships and resulted in a greater number of significant results (see Figures 1 and 2). In general, the conclusions drawn from the smaller sample size were accurate and the larger dataset confirms the negative impact of increased DO flux on biological communities.

Table 1. Raw DO flux threshold concentration values (mg L^{-1}) using additive quantile regression smoothing analysis. Abbreviations: T.C. = threshold concentration, MP = midpoint, UBP = upper break point, Fisher's = Fisher's exact test.

Region	Group	Metric	lambda	F-test	MP T.C.	MP test	UBP T.C.	UBP test	Final T.C.	Notes
Statewide	Fish	%Sensitive	3	<0.0001	7.1	9	4.1	28	4.1	use 1st breakpoint
Statewide	Fish	%Darter								weak relationship
Statewide	Fish	%Simple Lithophils	4	<0.0001	5.8	44	4.1	54	4.1	use 1st breakpoint
Statewide	Fish	%Tolerant	4	<0.0001	4.7	27	2.8	8	4.7	use midpoint
Statewide	Fish	%Insectivores	1.25	<0.0001	3.3	70	2.6	77		failed chi squared
Statewide	Fish	%Piscivores	2	<0.0001	6.0	8	4.1	14		failed chi squared
Statewide	Fish	%Intolerant	2	<0.0001	5.3	5	4.1	10	4.1	use 1st breakpoint
Statewide	Fish	Taxa Richness								weak relationship
Statewide	Invert	Taxa Richness	4	<0.0001	3.2	41	-	-		failed chi squared
Statewide	Invert	#Collector-Filterer	2	<0.0001	6.2	6	5.1	7		failed chi squared
Statewide	Invert	#Collector-Gatherer	5	<0.0001	3.6	14	-	-		failed chi squared
Statewide	Invert	#EPT	3	<0.0001	7.2	10	4.3	14		failed chi squared
Statewide	Invert	#Intolerant	3	<0.0001	7.1	4	4.1	7		failed chi squared
Statewide	Invert	%Tolerant	5	<0.0001	-	-	5.6	27		failed chi squared

Table 2. Raw DO flux threshold concentration values (mg L^{-1}) using regression tree (changepoint) analysis. Abbreviations: T.C. = threshold concentration, L = 90% lower bound, U = 90% upper bound, Fisher's = Fisher's exact test, chi squared = chi squared test.

Region	Group	Metric	Bucket	T.C.	L	U	test	Final T.C.	Notes
Statewide	Fish	%Sensitive	7	4.9	4.4	6.4	0.0020	4.9	chi squared
Statewide	Fish	%Darter	7	2.4	-1.2	5.1	0.3050		failed Fisher's
Statewide	Fish	%Simple Lithophils	7	4.5	3.8	5.0	0.0040	4.5	chi squared
Statewide	Fish	%Tolerant	7	4.7	3.4	6.1	<0.001	4.7	chi squared
Statewide	Fish	%Insectivores	7	3.1	-0.5	4.9	0.1870		failed chi squared
Statewide	Fish	%Piscivores	7	1.8	-3.3	3.7	0.0200	1.8	Fisher's
Statewide	Fish	%Intolerant	7	4.4	3.1	6.9	0.0060	4.4	chi squared
Statewide	Fish	Taxa Richness	7	5.8	4.2	9.4	0.097		failed chi squared
Statewide	Invert	Taxa Richness	6	4.9	2.4	6.6	0.0061	4.5	chi squared
Statewide	Invert	#Collector-Filterer	6	4.5	3.7	7.0	0.7862		failed chi squared
Statewide	Invert	#Collector-Gatherer	6	5.3	3.5	8.9	0.9889		failed chi squared
Statewide	Invert	#EPT	6	5.1	5.2	9.3	0.3005		failed chi squared
Statewide	Invert	#Intolerant	6	6.3	5.4	8.5	0.0789		failed Fisher's test
Statewide	Invert	%Tolerant	6	6.3	4.7	10.1	0.1300		failed chi squared

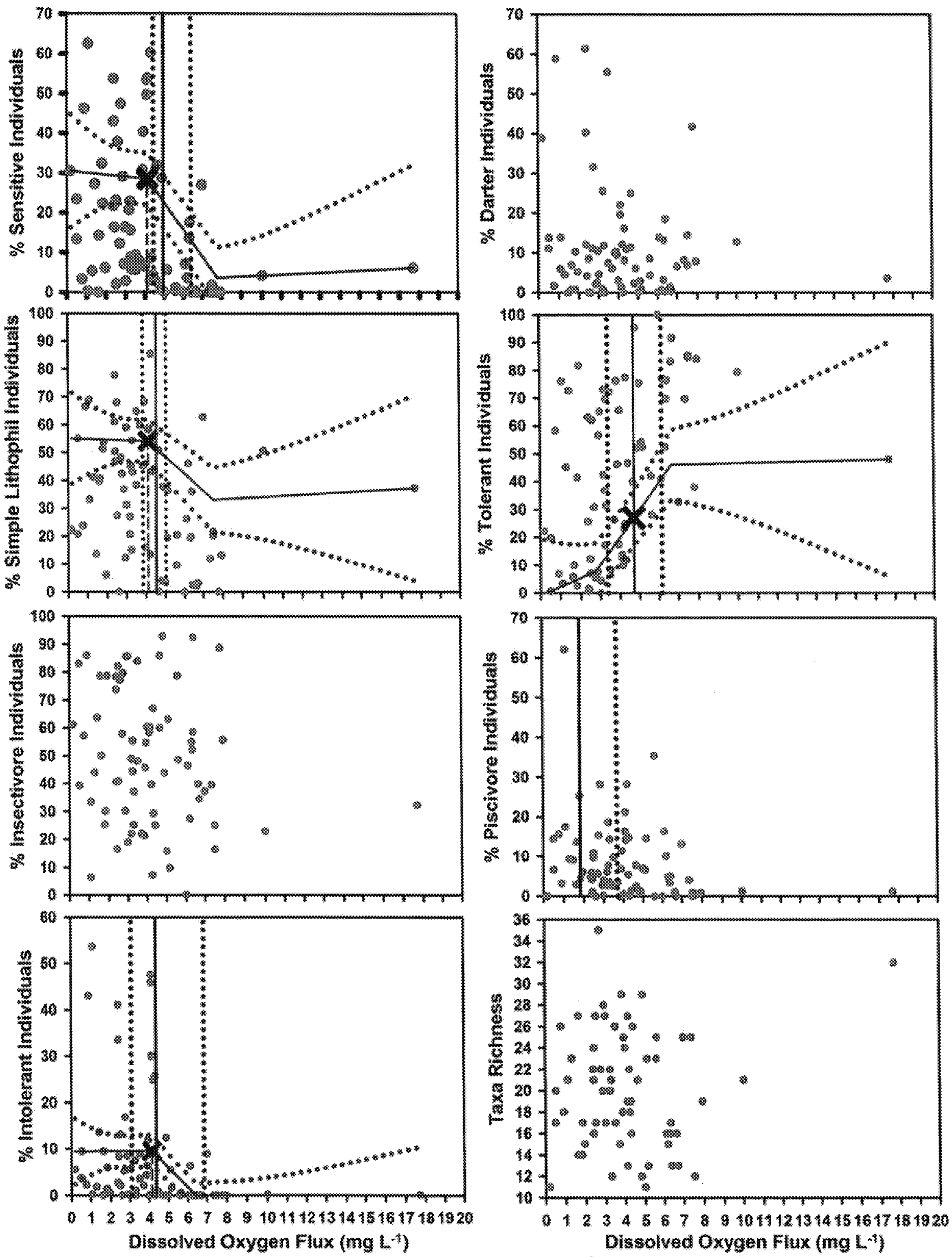


Figure 1. Relationships between Dissolved Oxygen Flux mg L^{-1} and fish metrics (red line = additive quantile regression with 90% confidence bands, blue line = changepoint with 90% confidence bands).

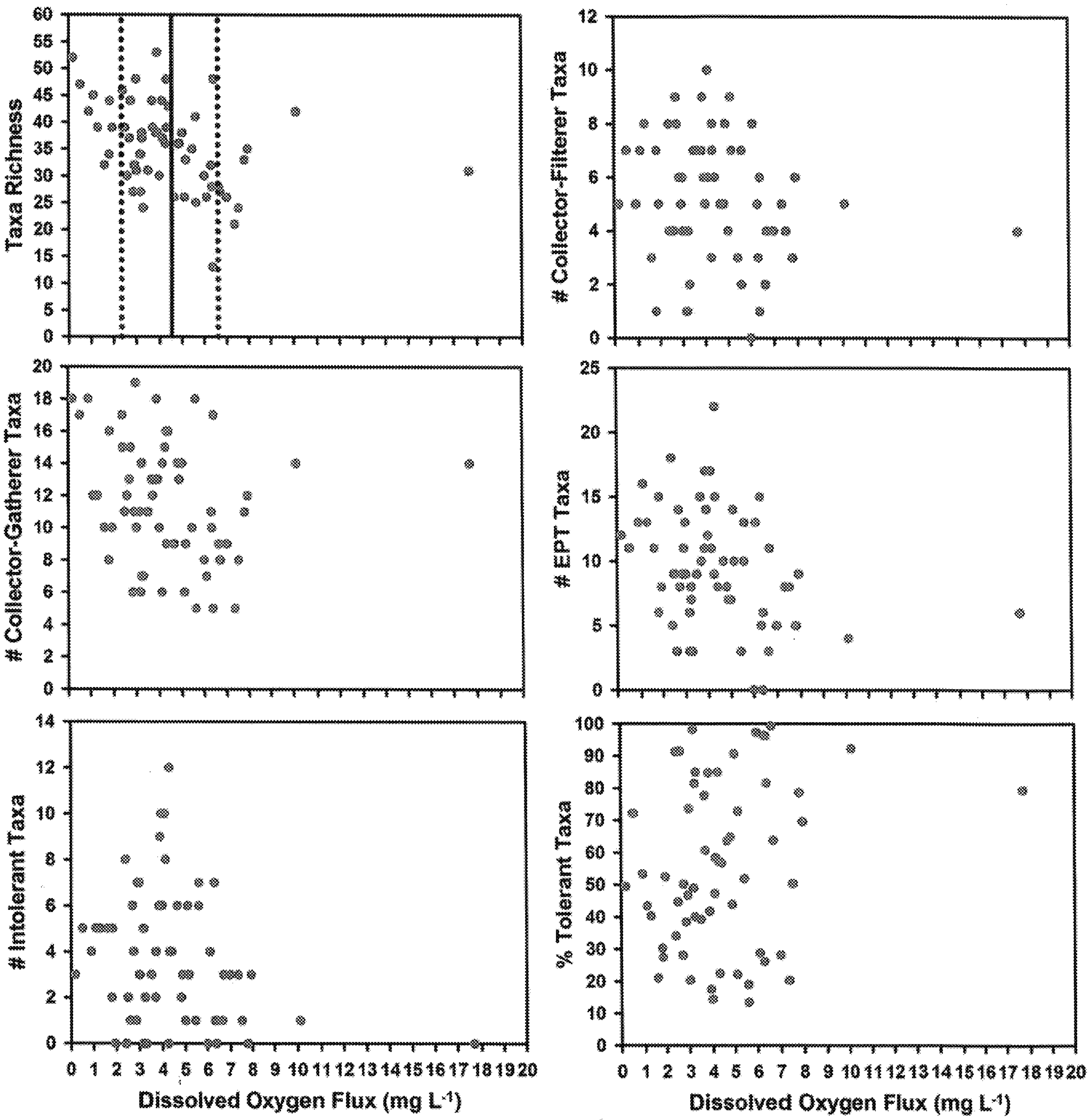


Figure 2. Relationships between Dissolved Oxygen Flux mg L^{-1} and macroinvertebrate metrics (red line = additive quantile regression with 90% confidence bands, blue line = changepoint with 90% confidence bands).

Section 2. Reference Condition Analysis

During the Public Hearing on January 8, 2014, MCEA questioned the validity of the approach used to identify reference sites for the reference condition analysis. To clarify the approach that the MPCA used and to demonstrate that the approach was not flawed we have generated a series of figures. These figures clarify the relationships between reference and non-reference sites and demonstrate that the process used to select reference sites did result in sites that could be used in this analysis. In addition, it is important to clarify that the MPCA did not blindly use the reference condition analysis and because of limitations of the analyses we did not rely on this analysis in the South region.

A description of the Human Disturbance Score used to select reference sites is provided in EU-1 pp. 25-26. Figures 3, 4, and 5 provide a comparison of the individual metric scores from the Human Disturbance Scores for the three regions. In all three regions it is clear that human activity is lower in reference sites versus the non-reference sites. Furthermore in the North and Central regions, there are low levels of each of the human activity measures (% agriculture, % impervious surface, etc.; Figures 3 and 4). These low levels indicate that most of these streams will have low stressor levels and healthy biological communities that can be used to inform goal setting. However the South region is different in that we see increased levels of activity that indicate possible stream health degradation beyond targeted goals (Figure 5). In addition, there were only 6 sites that met the reference site criteria in the South region which increases the uncertainty of statistics derived from this dataset. As a result, the reference condition analysis results were given very little weight in the South region as part of the multiple lines of evidence approach. In the Central region, the reference condition analysis was effective and it was useful in setting proposed criteria. However, increases in human activity in the Central region led us to give it less weight than the biological threshold analyses. In the North region where the reference sites selection was very effective, the reference condition analysis was given as much weight as the biological threshold analyses.

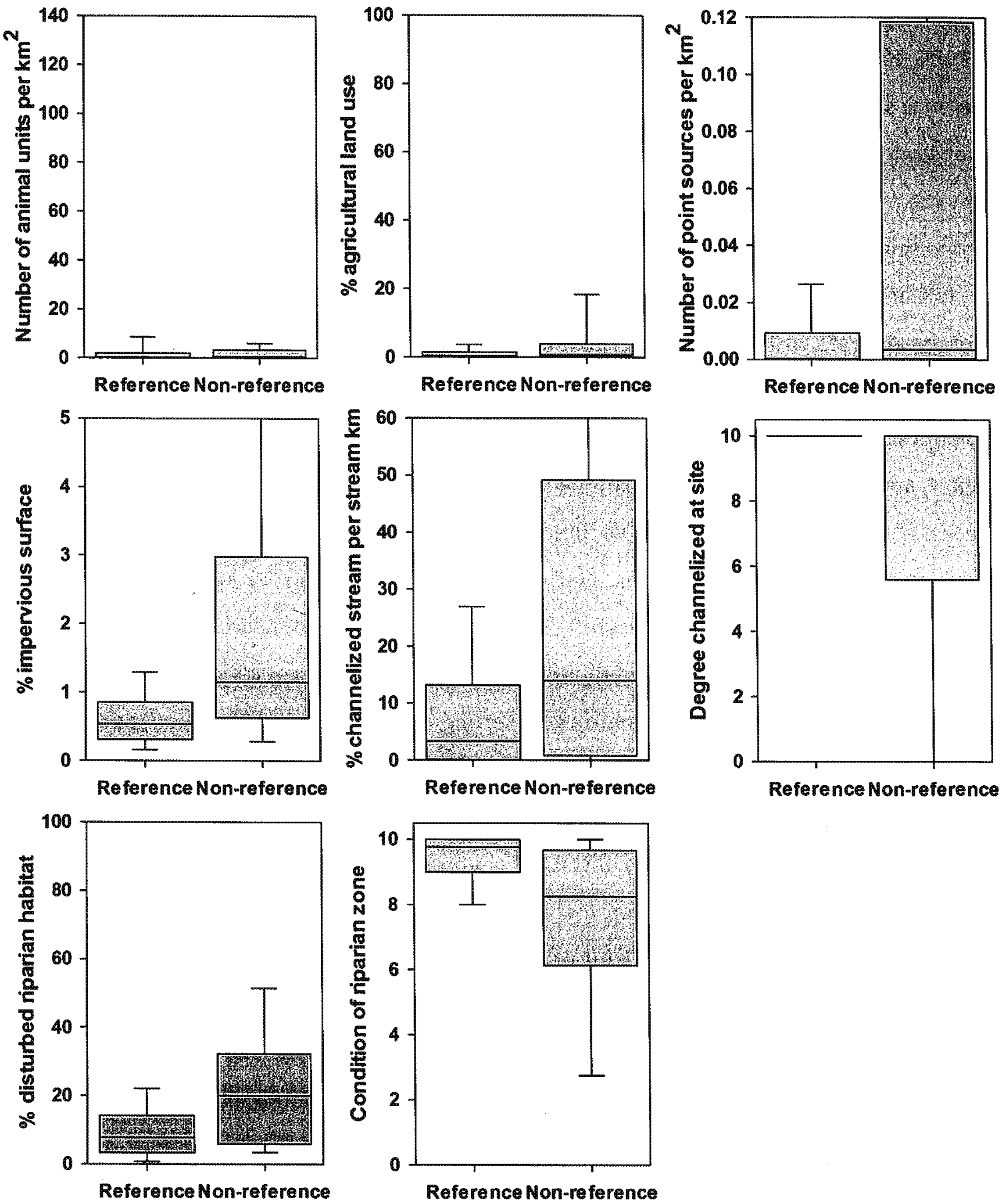


Figure 3. A comparison of Human Disturbance metric values for reference and non-reference sites for the North region. The degree of channelization is the proportion of reach that has a natural channel in 10% intervals (e.g., a score of 10 = 100% natural channel). Condition of the riparian zone is the average of % undisturbed from 0-30 m and 0-15 m buffers. Symbols: upper and lower bounds of box = 75th and 25th percentiles, middle bar in box = 50th percentile, upper and lower whisker caps = 90th and 10th percentiles.

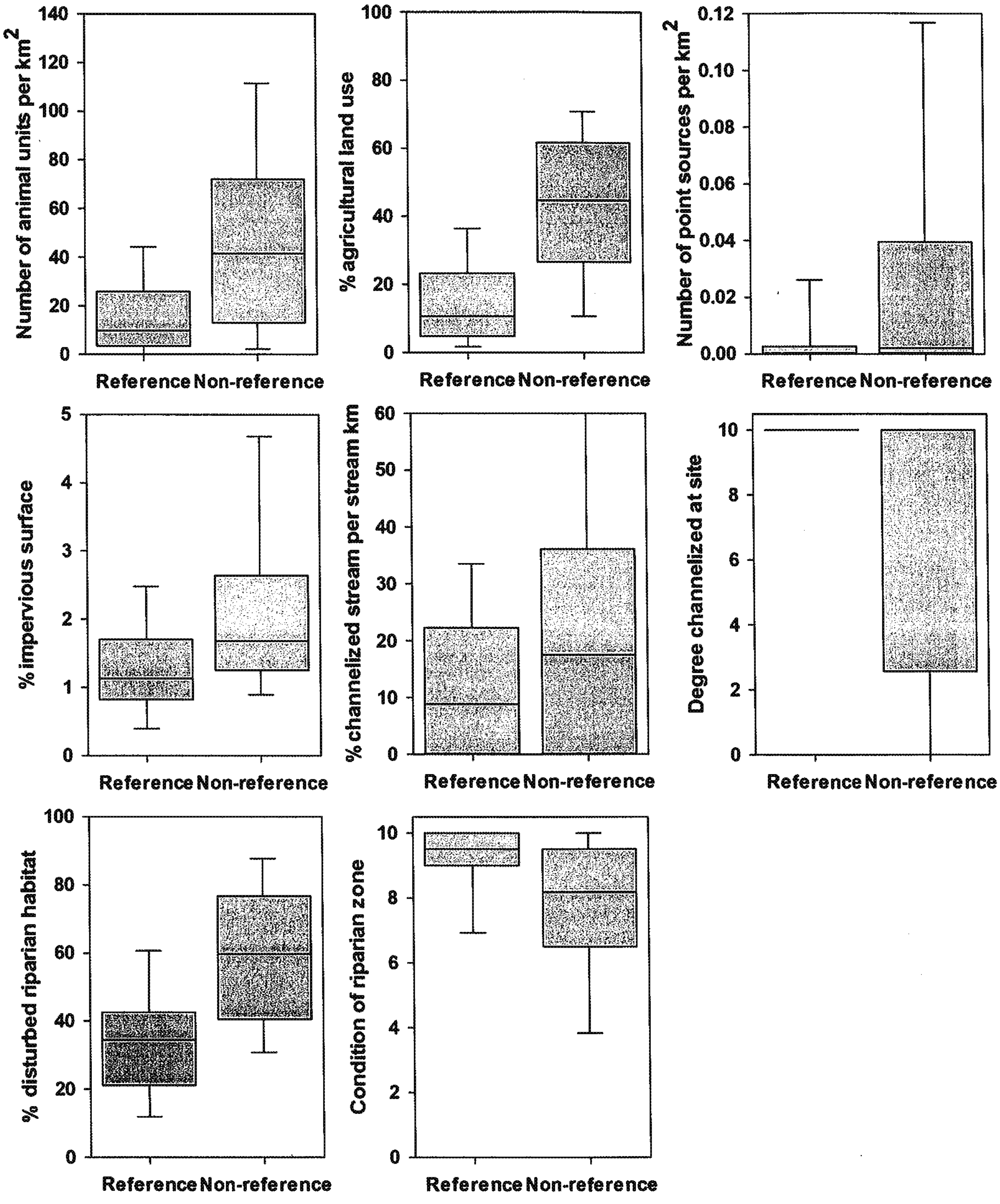


Figure 4. A comparison of Human Disturbance metric values for reference and non-reference sites for the Central region. The degree of channelization is the proportion of reach that has a natural channel in 10% intervals (e.g., a score of 10 = 100% natural channel). Condition of the riparian zone is the average of % undisturbed from 0-30 m and 0-15 m buffers. Symbols: upper and lower bounds of box = 75th and 25th percentiles, middle bar in box = 50th percentile, upper and lower whisker caps = 90th and 10th percentiles.

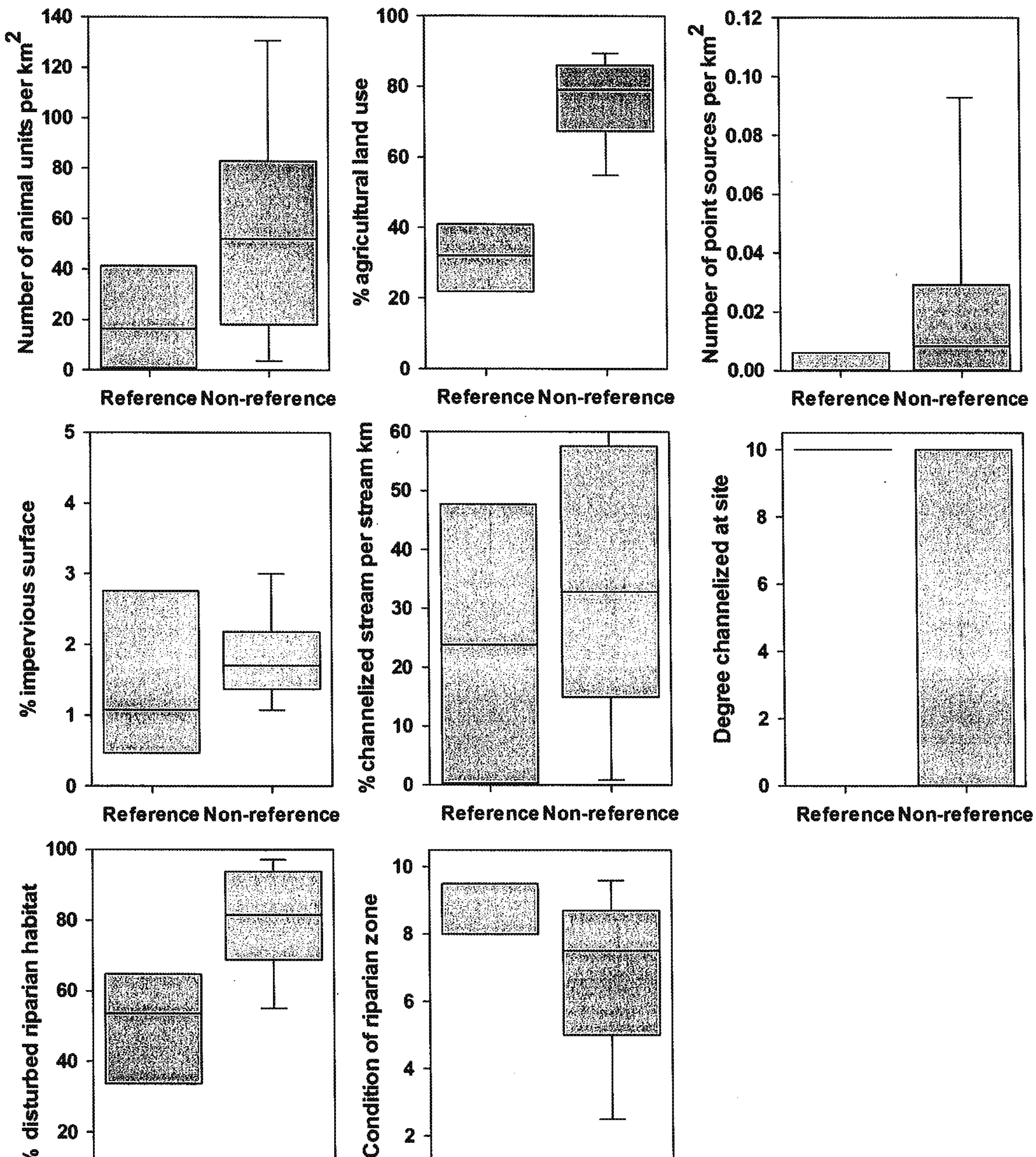


Figure 5. A comparison of Human Disturbance metric values for reference and non-reference sites for the South region. The degree of channelization is the proportion of reach that has a natural channel in 10% intervals (e.g., a score of 10 = 100% natural channel). Condition of the riparian zone is the average of % undisturbed from 0-30 m and 0-15 m buffers. Symbols: upper and lower bounds of box = 75th and 25th percentiles, middle bar in box = 50th percentile, upper and lower whisker caps = 90th and 10th percentiles.

Section 3. Quantile Regression Midpoint Analysis

During the Public Hearing on January 8, 2014, MCEA questioned the validity of the midpoint thresholds determined from the Additive Quantile Regression Smoothing (AQRS) analysis. Specifically, they argue that this threshold is not sufficiently protective and that only the 1st breakpoint from this analysis should be used. The MPCA disagrees that the midpoint threshold is not sufficiently protective when no 1st breakpoint is present. A comparison of thresholds from the changepoint analysis, the 1st breakpoint from AQRS, and the midpoint from AQRS indicate that no single method is most protective across regions (Table 3). In the North region, the change point analysis resulted in the most protective concentration. In the Central region, the 1st breakpoint was most protective and in the South the midpoint was most protective (although in the South region no 1st breakpoints could be identified). Furthermore, Burkholder suggested that the MPCA only use the 1st breakpoint and when no 1st breakpoint is present we rely on the changepoint analysis. The total phosphorus thresholds were reanalyzed using this approach. The 25th percentile of thresholds was unchanged for the Central and South regions (Central = 110 µg/L and South = 145 µg/L). By eliminating the midpoint thresholds the 25th percentile of thresholds for the North region dropped from 44 to 38 µg/L. However, since this is only one line of evidence it would not change the proposed criteria. Specifically, this change would only alter the weighted average of the lines of evidence from 56 to 54 µg/L (see Section 4, Table 4). The proposed concentration of 50 µg/L would therefore still be consistent with the evidence.

Table 3: Comparison of the total phosphorus 25th percentile of threshold concentrations for the changepoint analysis, the 1st breakpoint from AQRS, and the midpoint from AQRS (AQRS = Additive Quantile Regression Smoothing).

	Changepoint	AQRS 1st Breakpoint	AQRS Midpoint
North	40	49	51
Central	142	92	113
South	145	-	138

Section 4. Derivation of Proposed Criteria from Multiple Lines of Evidence

To better define the approach MPCA used to derive the final proposed criteria from the multiple lines of evidence, we have revised our description of this process as described in pages 59-63 Book II SONAR (HE-3). The improved description follows:

The MPCA used multiple data analyses to statistically define interrelationships and threshold concentrations for total phosphorus (TP) and associated stressors. In this approach, the various interrelationships among variables, as depicted in EU-1, Figure 1, are established and when combined with supporting information, provide a basis for establishing region-specific eutrophication criteria. This approach does not rely primarily on the reference condition, a recommended approach in early EPA guidance (Book II Exhibits EU-10-12 and 14), for eutrophication criteria selection. Instead, our approach emphasized threshold concentrations (TCs) developed from the biomonitoring data using AQRS and regression tree (RT; also referred to as changepoint) analysis, because this evidence is linked directly to biological performance and aquatic life use goals. The process of using multiple lines of evidence required a weighting of the available lines of evidence depending on the strengths each line of evidence and differences between regions and stressors. The recommended criteria were therefore, not the result of a strict averaging of the thresholds from the available evidence because the strengths of these results varied between regions and datasets. Rather, it was an approach that weighted some evidence greater than others and acknowledged that the relative importance of the various lines of evidence varied among regions.

Table 4. Summary of evidence used to develop regional river eutrophication criteria recommendations (weighting criteria is provided in parentheses, P25 = 25th percentile, P75 = 75th percentile, TP = Total Phosphorus).

Line of Evidence	TP ($\mu g\ L^{-1}$)
North	
1. P25 Threshold Concentrations	44 (2)
2. P75 for MN Reference Sites	61 (2)
3. Predicted Concentration Using Serial Regressions	72 (1)
Weighted Average Concentration	**56**
Recommended Criterion	**50**
Central	
1. P25 Threshold Concentrations	110 (2)
2. P75 for MN Reference Sites	120 (1)
3. Predicted Concentration Using Serial Regressions	107 (1)
Weighted Average Concentration	**112**
Recommended Criterion	**100**
South	
1. P25 Threshold Concentrations	145 (1)
2. P75 for MN Reference Sites	347 (0.5)
3. Predicted Concentration Using Serial Regressions	149 (1)
Weighted Average Concentration	**187**
Recommended Criterion	**150**

North River Nutrient Region Criteria Development. Rivers in the North River Nutrient Region (RNR) drain landscapes dominated by forest and wetland land uses. These rivers, by comparison to their counterparts in the Central and South regions, have minimal anthropogenic impacts relative to excess nutrients. Given these characteristics, it is relatively easy to find streams to characterize "reference" condition. The 25th percentile values from AQRS and RT for all stream sizes in the North was 44 $\mu g\ L^{-1}$ (Table 4). The 75th percentile of TP concentrations for reference sites in the North region was 61 $\mu g\ L^{-1}$ (Table 4). The serial regression analysis produced a TP threshold of 72 $\mu g\ L^{-1}$ (Table 4). The weighted average of the biological thresholds, reference analysis, and serial regression was 56 $\mu g\ L^{-1}$. Because of the large number of thresholds from the AQRS and RT analyses and the lower (i.e., more protective) value from these tests (Table 4) we chose to emphasize this line of evidence and "round" the weighted average value from all three lines down to 50 $\mu g\ L^{-1}$. For perspective, 50 $\mu g\ L^{-1}$ is within the interquartile (IQ) range based on representative minimally impacted Minnesota streams (Exhibit EU-30) and USEPA's criteria summary for the North ecoregions (Exhibit EU-12) and is near the median for the North RNR. 50 $\mu g\ L^{-1}$ is also below most reported thresholds in the literature for regions in the Upper Midwest of the United States, which is appropriate given this region is dominated by forest and wetland land uses.

Central River Nutrient Region Criteria Development. The Central RNR is a transitional area between the forest and wetland dominated North RNR and agriculturally dominated South RNR. Because of differing soils, landform, and potential natural vegetation, streams draining the Central RNR landscapes are more nutrient-rich than in the North RNR (Exhibits EU-11 & 12). However, this region is characterized by a wide range of stream conditions which includes both high quality and degraded systems. The 25th percentile TP TCs from AQRS and RT in the Central region was 110 µg L^{-1} (Table 4). The 75th percentile of TP concentrations for reference sites in the Central region was 120 µg L^{-1} (Table 4). Based on the serial regressions using the BOD_5 thresholds, a TP concentration of 107 µg L^{-1} will meet a BOD_5 of 2.1 mg L^{-1} in most systems (Table 4). A weighted mean of these lines of evidence was 112 mg L^{-1}. Based on these considerations and literature-based values, we rounded down to 100 µg/L to ensure the proposed TP criterion was adequately protective of aquatic life. 100 µg L^{-1} is within the range for Minnesota's minimally impacted streams and USEPA's criteria summary for the Central region (Exhibits EU-30 & 11).

South River Nutrient Region Criteria Development. The South RNR is characterized by agricultural land uses with cultivated landuse being dominant in this region. These land uses are a reflection of the soils, landforms, and potential natural vegetation that are characteristic of the Northern Glaciated Plains, Western Corn Belt Plains, and Lake Agassiz Plain ecoregions. These factors result in more nutrient-rich streams in this RNR as compared to the North or Central RNRs (Exhibit EU-10). Given these characteristics, it was difficult to identify minimally disturbed or least disturbed reference sites in this region. The 25th percentile of the biological thresholds TP values for all stream sizes in the South was 145 µg L^{-1} (Table 4). Based on the serial regressions using the BOD_5 biological threshold (Table 4), the corresponding protective concentration was 149 µg L^{-1} for TP. Only a small number of reference sites (n=6) were present in the South region so the 75th percentile of reference sites (347 µg L^{-1}) was given little to no weight in this analysis. In the absence of an adequate reference dataset, the 25th percentile TP of all values from the STORET dataset (146 µg L^{-1}, n =206) could be used as a line of evidence (Exhibit EU-14). Based on the available lines of evidence, a TP value of 150 µg L^{-1} was selected. While the South RNR TP criterion is relatively "high" compared to literature values, it is lower than the 25th percentile of previous MPCA and EPA regional data summaries (Exhibits EU-30 & 10).

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Minnesota's approach to lake nutrient criteria development

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Abstract

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Ecoregion-based phosphorus "criteria" that reflect the diversity of lake condition, varying from deep pristine lakes in the north to shallow hypereutrophic lakes in the south, were developed by the Minnesota Pollution Control Agency (MPCA) in the late 1980s. Since then the criteria, including several refinements, have been widely used for local, state, and federal lake watershed management efforts in Minnesota. More recently, the criteria have been used to define thresholds for Clean Water Act Section 303(d) listing of nutrient-impaired lakes and are being advanced as lake standards to protect a wide diversity of beneficial uses. This paper summarizes the evolution of these criteria and describes data and research used in their development. A weight-of-evidence approach describes how this information was used to refine the criteria values.

Key words: ecoregions, eutrophication, nutrient criteria, water quality standards

Minnesota has a diverse lake resource ranging from its northern boreal forests with cold/cool water fisheries to very productive shallow water lakes of the predominantly agricultural south. As such, substantial geographic patterns in lake water quality, morphometry, fisheries, and even user perceptions of what constitutes acceptable water quality are evident. Understanding of these regional patterns advanced substantially with the introduction of United States Environmental Protection Agency's (USEPA) aquatic ecoregion framework in the mid-1980s that ultimately became a foundation for organizing and communicating lake and watershed management information in Minnesota. This manuscript describes Minnesota's approach to developing nutrient criteria to provide a potential framework for states, provinces, or other entities that may need to develop eutrophication criteria to manage their lakes.

A single total phosphorus (TP) value could not be adopted as a statewide criterion for lake protection in Minnesota due to regional differences and diversity of lake types (Heiskary *et al.* 1987). Rather, a methodology was needed for developing phosphorus (P) criteria on a regional and lake/watershed specific basis. The methodology for establishing P criteria in Minnesota considered the following (Heiskary and Walker 1988):

1) P impacts on lake condition (as measured by chlorophyll *a*, bloom frequency, transparency, and hypolimnetic oxygen depletion)
2) impacts on lake users (*e.g.*, aesthetics, recreation, fisheries, water supply)
3) linkages of watershed mass-balance and associated goal setting approaches.

An important first step of the criteria-setting process requires the definition of "most sensitive uses" of lakes. A sensitive use of a lake is defined as a beneficial use (or uses) that can be affected or even lost as a result of an increase in the trophic status of the lake, such as coldwater fisheries and aquatic recreational use (*e.g.*, swimming). In a coldwater fishery, increased nutrient loading results in a reduction of oxygen in the hypolimnion, and die-offs of coldwater species may occur as these populations are driven into warmer metalimnetic and epilimnetic waters. For aquatic recreational use, excess P stimulates algal growth that can lead to frequent and severe nuisance blooms and reduced transparency that will limit use of the resource. Most sensitive uses have been identified for each region and appropriate TP, chlorophyll *a* (Chl-*a*) and Secchi disk transparency (referred to as Secchi hereafter) criteria, deemed to be protective of that use, are defined (Table 1). These criteria are ecoregion-based and reflect several considerations, including: regional patterns in lake condition; detailed information from ecoregion reference

Table 1.-Minnesota's lake eutrophication criteria. Criteria are defined by ecoregion for specific lake types and uses (official use classification noted). TP and chlorophyll *a* should remain below these concentrations and Secchi should be not less than this value to ensure that the specific use is maintained.

Ecoregion – lake type (use classification[1])	TP µg/L	Chl-*a* µg/L	Secchi meters
NLF – Designated Lake trout (Class 2A)	12	3	4.8
NLF – Designated Stream trout (Class 2B)	20	6	2.5
NLF – Aquatic Rec. Use (Class 2B)	30	9	2.0
CHF – Designated Stream trout (Class 2B)	20	6	2.5
CHF – Aquatic Rec. Use – Deep (Class 2B)	40	14	1.4
CHF – Aquatic Rec. Use – Shallow (Class 2B)	60	20	1.0
WCP&NGP – Aquatic Rec. Use – Deep (Class 2B)	65	22	0.9
WCP&NGP – Aquatic Rec. Use - Shallow (Class 2B)	90	30	0.7

[1] Aquatic life and recreation use class as defined in Minn. R. 7050.0140, subp. 3 and Minn. R. 7050.0222 (Minnesota Rules Chapter 7050 2007). Class 2A is used for waters supporting a cold water fishery and refers specifically to lakes that support natural populations of lake trout. Stream trout refers to all other designated (managed) trout lakes. Class 2B is designation for waters supporting cool or warm water fishery and is the default classification for the majority of Minnesota's lakes.

lakes; background trophic status based on sediment diatom reconstruction of TP; interrelationships among TP, Chl-*a*, Secchi and nuisance algal bloom frequency; lake morphometry; lake-user perception; and lake ecology (including fishery composition and rooted macrophyte extent and diversity).

The following sections of the manuscript describe how the criteria are derived:

- *Methods and Database Development* section describes the data used to develop the criteria.
- *Results* section describes regional patterns, interrelationships among important parameters (*e.g.*, TP, Chl-*a*, Secchi, nuisance bloom frequency) and factors such as fishery composition, macrophyte diversity, and user perception that were essential to identifying criteria thresholds.
- *Discussion* section describes how these patterns, databases, and interrelationships are used in a weight-of-evidence approach to select criteria values. An ecoregion-specific example provides details on how this was done for one of the ecoregions.

Methods and database development

Several databases are referred to in this report. Brief descriptions are presented for the four primary databases: *assessment*, *reference*, *diatom-inferred phosphorus* and *USEPA criteria*. Each database is important to the overall assessment of Minnesota lakes and criteria development efforts. Water quality data from all databases may be found in STORET. Relevant field and laboratory methods and quality assurance information, which applies to the three Minnesota databases, are summarized.

Field and laboratory methods

Water quality data were collected during the summer (Jun to Sep). Sampling stations were typically located at mid-lake at the greatest lake depth. Surface samples were generally collected with a 2-m long, 3.2 cm i.d. PVC tube that integrates a 2-L sample from the upper 2 m of the lake. Field measurements routinely include Secchi transparency, dissolved oxygen (DO), and temperature profiles, and subjective measures of the physical appearance and recreational suitability of the lake.

The Minnesota Department of Health (MDH) laboratory analyzed samples collected by the Minnesota Pollution Control Agency (MPCA). Total P and total Kjeldahl nitrogen (TKN) samples were acid-preserved at the time of collection. Chlorophyll *a* samples were chilled and kept in the dark immediately after collection. Samples were filtered through 0.45-µm diameter glass fiber filters within 8 hr of collection and kept frozen until analyzed. Samples were analyzed by spectrophotometer and corrected for pheophytin. Commonly measured analytes, methods, reporting limits, and laboratory precision were summarized (Table 2).

Databases

Assessment database

The *assessment* database includes all Minnesota lake stations in STORET with data for one or more of the trophic status

Table 2.-Minnesota Department of Health laboratory method and precision estimates.

Analyte	Reporting Limit & Units	EPA method number	Precision[1]: mean difference	Difference as Percent of observed
Total Phosphorus	10.0 µg/L	365.2	4.8 µg/L	2.7 %
Total Kjeldahl N	0.1 mg/L	351.2	0.05 mg/L	2.8 %
$NO_2 + NO_3$	0.01 mg/L	353.1		
Total Suspended Solids	0.5 mg/L	160.2	2.8 mg/L	9.6 %
Total Suspended Volatile Solids	0.5 mg./L	160.4	--	--
Chlorophyll *a*	0.16 µg/L	446.0	1.7 µg/L	7.4 %
Pheophytin	0.27 µg/L	446.0	--	--

[1] Average of individual means of 10 duplicates and expressed as a % of measured concentrations.

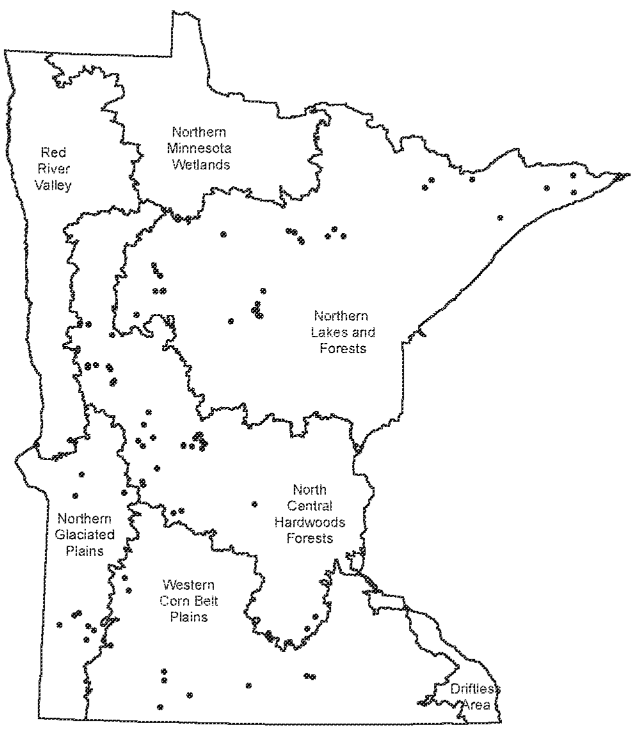

Figure 1.-Minnesota's ecoregions with reference lake locations noted for the four ecoregions that contain 98% of Minnesota's lakes: Northern Lakes and Forests (NLF), North Central Hardwoods Forests (CHF), Western Corn Belt Plains (WCP) and Northern Glaciated Plains (NGP).

variables (TP, Chl-*a*, or Secchi transparency) and includes data for approximately 2,790 lakes, collected during the past 32 years (1970–2002). The data were collected by the MPCA, Metropolitan Council Environmental Services (MCES), Minnesota Department of Natural Resources (MDNR), citizen volunteers, and numerous other entities. The majority of the Secchi and "user perception" data were obtained through the MPCA's volunteer Citizen Lake-Monitoring Program (CLMP). Summer means and supporting statistics were calculated for each trophic state variable. A complete explanation of the process and individual lake data are available on the MCPA web site: http://www.pca.state.mn.us/water/lakequality.html.

Ecoregion reference lake database

The *reference lake* database and is a subset of the *assessment* database. The aquatic ecoregion framework (Omernik 1987) was used as a basis for selecting these lakes and analyzing the data. The *reference lake* database is comprised of approximately 90 representative and minimally impacted lakes distributed among the four ecoregions that contain 98% of Minnesota's lakes by number: predominantly forested Northern Lakes and Forests (NLF), the predominantly agricultural Western Corn Belt Plains (WCP), and Northern Glaciated Plains (NGP), and the transitional ecoregion, the North Central Hardwood Forests (CHF) of central Minnesota (Fig. 1). Maximum depth, surface area, and fishery classification were considered in selecting representative lakes for each ecoregion (details in Heiskary and Wilson 1989, 2005).

Diatom-inferred phosphorus database

The *diatom-inferred phosphorus* database was developed based on lake-sediment core, diatom-inferred TP data as derived from three separate, but related, studies:

- "55 Lakes Study" included lakes from the NLF (20), urbanized portion of CHF (20), rural portion of CHF (10), and WCP (5) ecoregions. Surface and deep (1–2 m) cores were taken from all lakes. Core-sections corresponding to *circa* 1750, 1800, 1970, and 1993 time-periods were used in this analysis. Fossil diatoms were identified and enumerated in each of these samples. Predictive models were developed based on modern-day water quality

Table 3.-*Assessment* database summary by ecoregion. Percentile values and number of lakes assessed for lake surface area, maximum depth and summer-mean total phosphorus by ecoregion.

		Percentile					
Ecoregion	**Parameter**	**10**	**25**	**50**	**75**	**90**	**N**
NLF	Area (ha)	22	49	129	347	835	1,809
NLF	Depth-max. (m)	10	19	33	54	80	1,519
NLF	TP (µg/L)	9	13	21	30	45	863
CHF	Area (ha)	22	58	165	400	984	976
CHF	Depth-max. (m)	8	16	28	46	68	829
CHF	TP (µg/L)	18	28	51	112	229	691
WCP	Area (ha)	61	143	322	694	1,776	110
WCP	Depth-max. (m)	6	7	10	16	25	87
WCP	TP (µg/L)	62	99	159	234	404	89
NGP	Area (ha)	108	150	364	658	2,091	38
NGP	Depth-max. (m)	5	8	10	15	18	28
NGP	TP (µg/L)	54	104	148	194	396	30

(*circa* 1993) and diatom populations in these lakes. The models were then used to predict pre-European TP and other water quality parameters. Details on the actual reconstruction techniques and models are found in Ramstack *et al.* (2003 and 2004), Heiskary *et al.* (2004), and Heiskary and Swain (2002). Methods used in this study are generally applicable to the following two studies as well.

- "Southwest Shallow Lakes Study" included about 25 shallow lakes distributed across the WCP and NGP ecoregions. Surface sediments were collected on all lakes and deep cores were taken from seven lakes. Details on this study may be found in Heiskary *et al.* (2003).
- "West-Central Shallow Lakes Study" focused on 31 lakes in west-central Minnesota (primarily in the CHF ecoregion). These lakes provided the primary basis for characterizing interrelationships among aquatic macrophytes, lake trophic status, and related variables. Of the 31 lakes, six had deep sediment cores collected. Details on this study may be found in Heiskary and Lindon (2005). Data from these two studies are referred to as *shallow lakes* data.

USEPA criteria development database

The *USEPA criteria database* is drawn from the USEPA (2000a–c) criteria documents. Though much of the data are from Minnesota and overlap with the *assessment* database, this database provides larger datasets than available for only Minnesota because it contains data from neighboring states in the same ecoregion. Data in the criteria documents were drawn primarily from STORET for 1990–1999. Statistical distributions for various trophic status measurements are presented by aggregated ecoregion, level III ecoregions, and by season. Compiled statistics for lakes in the level III ecoregions for the summer index period served to complement the Minnesota databases.

Results

Regional patterns

Initial efforts concentrated on defining interrelationships among the trophic status variables (TP, total nitrogen [TN], Chl-*a*, and Secchi transparency) and how trophic status relationships vary within and among regions. Previous publications have addressed patterns in lake trophic status in Minnesota (Moyle 1956, Heiskary *et al.* 1987, Heiskary and Wilson 1989). A central theme in these descriptions and analysis is an emphasis on the central tendency of the data, as indicated by the interquartile (IQ) range (values from the 25th to 75th percentile), which is also referred to as the "typical range" in the context of this paper.

Regional patterns: trophic status interrelationships

The *assessment* database provides sufficient information to examine general patterns of trophic status (TP, Chl-*a*, and Secchi) and lake morphometry among regions. Northern to mid-Minnesota lakes (*i.e.*, NLF and CHF ecoregions) have similar morphometry in terms of surface area and maximum depth (Table 3). Likewise, the two southern agricultural ecoregions, WCP and NGP, exhibit similar morphometry

Table 4.-*Reference lake* database summary. Typical (interquartile) range of summer-mean water quality, lake morphometric or watershed characteristic based on the reference lakes for each ecoregion.

	Ecoregion			
Parameter	**NLF**	**CHF**	**WCP**	**NGP**
# of lakes	32	43	16	13
Area (ha)	61 – 208	74 – 297	75 – 168	198 – 258
Depth-mean (m)	2.5 – 10.5	4.8 – 7.9	1.9 – 3.4	1.5 – 1.8
Depth-max. (m)	9.1 – 24.1	13.0 – 22.0	3.0 – 8.2	2.0 – 3.0
Watershed land use				
% forested	54 - 81%	6 – 25%	0 – 15%	0 – 1%
% wetland	14 – 31%	14 – 30%	3 – 26%	8 – 26%
% cultivated	0 – 1%	22 – 50%	42 – 75%	60 – 82%
% pasture	0 – 6%	11 – 25%	0 – 7%	5 – 15%
Total P (µg/L)	14 – 27	23 – 50	65 – 150	122 – 160
Chl-*a* mean (µg/L)	4 – 10	5 – 22	30 – 80	36 – 61
Chl-*a* max. (µg/L)	10 – 15	7 – 37	60 – 140	66 – 88
Secchi disk (m)	2.4 - 4.6	1.5 – 3.2	0.5 – 1.0	0.4 – 0.8
T.Kjeldahl N(mg/L)	0.4 – 0.75	< 0.60 – 1.2	1.3–2.7	1.8 – 2.3
NO2+NO3-N (mg/L)	<0.01	<0.01	0.01 – 0.02	0.01 – 0.1
TN:TP ratio	25:1 – 35:1	25:1 – 35:1	17:1 – 27:1	13:1 – 17:1
Alkalinity (mg/l)	40 – 140	75 –150	125 – 165	160 – 260
Color (Pt-Co Units)	10 – 35	10 – 20	15 – 25	20 – 30
pH (SU)	7.2 – 8.3	8.6 – 8.8	8.2 – 9.0	8.3 – 8.6
Chloride (mg/L)	0.6 – 1.2	4 – 10	13 – 22	11 – 18
T Suspended. Sed. (mg/L)	< 1 – 2	2 – 6	7 – 18	10 – 30
Sus. Inorganic Sed. (mg/L)	< 1 – 2	1 – 2	3 – 9	5 – 15
Turbidity (NTU)	1– 2	1 – 2	3 – 8	6 –17
Cond. (umhos/cm)	50 – 250	300 – 400	300 – 650	640 – 900

and tend to be larger and much shallower than the NLF and CHF lakes. Distinct regional differences in the distribution of lake trophic status are evident among some regions (*e.g.*, NLF and WCP), while substantial overlap exists among others (*e.g.*, WCP and NGP). For example, the typical range of TP varies from mesotrophic to mildly eutrophic (13–30 µg/L) in the NLF, mildly eutrophic to hypereutrophic (28 to >100 µg/L) in the CHF, and hypereutrophic (>100 µg/L) in the WCP and NGP. Regional differences are evident for Chl-*a* and Secchi as well (Table 3).

Regional differences in lake morphometry, watershed land use, and water quality are further evident in the *reference lake* data (Table 4). These differences have been described in various publications (*e.g.*, Heiskary and Wilson 1989) and only a brief overview is offered here. Lakes in the NLF ecoregion are moderately deep with watersheds dominated by forest and wetland land uses, and trophic status is typically oligotrophic to mesotrophic (TP = 14–27 µg/L). Lakes in the CHF ecoregion are also moderately deep with watersheds characterized by a mosaic of land uses, and trophic status is typically mesotrophic to mildly eutrophic range (TP = 23–50 µg/L). Lakes in the WCP and NGP ecoregions are predominately shallow with dominant agricultural land use, and typical trophic status ranges from eutrophic to hypereutrophic (TP = 65–160 µg/L). Inorganic suspended solids (*i.e.*, clay and soil particles) are high in these shallow windswept lakes and, in addition to algae, contribute to the very low Secchi transparency (Table 4). When all factors are considered, two very distinct classes (regions) are evident: forest dominated (NLF) and agriculture dominated (WCP and NGP). The transitional zone (CHF) between these two extremes shares characteristics of these two classes but presents management problems unique to this ecoregion.

Initial efforts focused on defining relationships among TP, Chl-*a*, and Secchi transparency using Carlson's TSI scale (Carlson 1977). Following Carlson's methodology, Minnesota-based regressions were developed based on the *reference lake* data (in m and µg/L):

$$\mathrm{Log_{10}\,Chl}\text{-}a = 1.31\ \mathrm{Log_{10}\,TP} - 0.95 \qquad (1)$$
$R^2 = 0.88$; n = 108

$$\mathrm{Log_{10}\,Secchi} = -0.59\ \mathrm{Log_{10}\,Chl}\text{-}a + 0.89 \qquad (2)$$
$R^2 = 0.85$; n = 108

$$\mathrm{Log_{10}\,Secchi} = -0.81\ \mathrm{Log_{10}\,TP} + 1.51 \qquad (3)$$
$R^2 = 0.81$; n = 108

Comparative studies of freshwater eutrophication strongly suggest that efforts to control external nutrient loading to lakes tend to achieve similar reductions in their average algal biomass (Smith 2003). However, Smith notes that growing season average biomass (Chl-*a*) is probably not consciously measured by lake users as a primary index of impairment, hence the need to define peak events that occur over the summer growing season. The *reference lake* data provide a basis for predicting extreme Chl-*a* values as a function of the summer-mean:

$$\mathrm{Chl}\text{-}a\ (\mathrm{max}) = 1.33\ \mathrm{Chl}\text{-}a\ (\mathrm{mean}) + 5.15 \qquad (4)$$
$R^2 = 0.89$; n = 108

Walker (1984) took this relationship a step further by associating the mean with the frequency of various classes or levels of Chl-*a*, referred to as "bloom frequency." An expansion on this approach examined the interrelationships of TP, Chl-*a*, and transparency (*i.e.*, "lake response") by using cross-tabulation based on about 640 paired TP, Chl-*a*, and Secchi measurements from the reference database (Heiskary and Walker 1988). The resulting relationship among TP and nuisance-level frequencies of Chl-*a* (Fig. 2a) provided a basis for assessing the "risk" of encountering nuisance level frequencies of Chl-*a*. Nuisance levels were defined based on previous work by Walmsley (1984) for South African reservoirs and perceptions of Minnesota lake users: Chl-*a* > 10 µg/L = mild bloom; > 20 µg/L = nuisance bloom; > 30 µg/L = severe nuisance bloom; and > 60 µg/L = very severe nuisance bloom. The phrase "nuisance criteria" refers to specific Chl-*a* or transparency levels that result in perceived impairment, and these perceptions may vary among states and ecoregions. The State of Florida, for example, uses Chl-*a* > 40 µg/L as an indication of an algal bloom (Bachmann *et al.* 2003).

Analysis of 170 pairs of TP and Chl-*a* data from the *shallow lakes* showed a slightly different "bloom frequency" response (Fig. 2b) as compared to the *reference lakes* (Fig. 2a). As TP increase from about 50 to 75 µg/L, the frequency of severe nuisance blooms increases rather dramatically; however, very

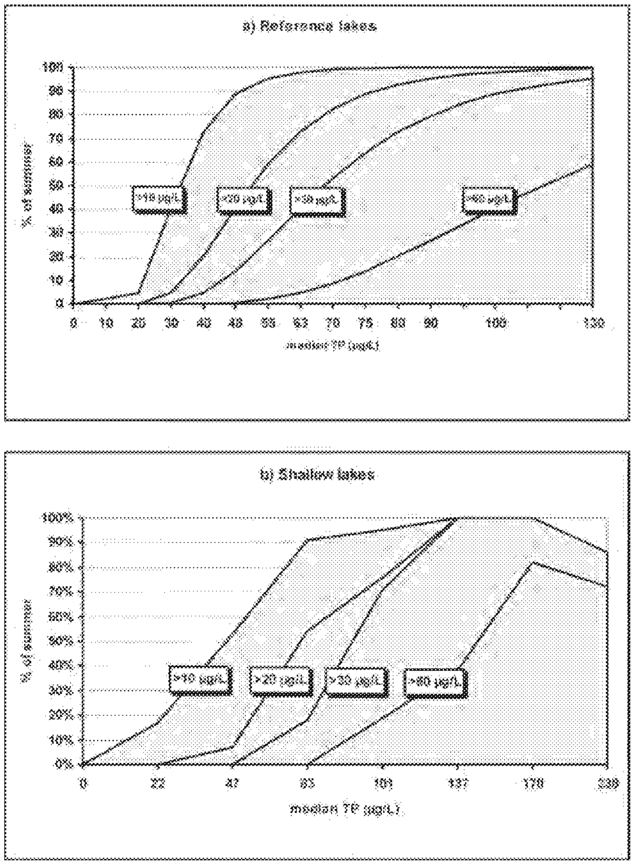

Figure 2.-Algal bloom frequency as a function of total phosphorus (TP) for: (a) reference lakes (based on 641 paired TP and Chl-*a* measurements) and (b) shallow lakes (based on 170 paired measurements). Median TP for the interval noted. Four "classes" of bloom intensity noted ranging from "mild bloom" (Chl-*a* > 10 µg/L) to "very severe nuisance blooms" (Chl-*a* > 60 µg/L).

severe nuisance blooms remain at a relatively low frequency (Fig. 2b). A second inflection point occurs as TP increases from about 90 µg/L to 120 µg/L, whereby the frequency of severe nuisance blooms increases to about 70% of the summer and very severe nuisance blooms (Chl-*a* > 60 µg/L) occur about 40% of the summer.

Regional patterns: lake morphometry, mixing, and trophic status

Previous investigators recognized that lake morphometry, in addition to watershed factors, plays an important role in determining lake productivity (Rawson 1952, Riley and Prepas 1985). These factors must also be considered when developing lake nutrient criteria because they may influence TP, Chl-*a*, and Secchi relationships; species of fish that may be found in the lake; internal nutrient recycling; and/or whether primary productivity is expressed primarily through rooted submerged vegetation or through phytoplankton.

Table 5.-Summer-mean total phosphorus (µg/L) distribution by mixing status and ecoregion. Based on lakes in *assessment database* (Heiskary and Wilson 2005): Dimictic = D, Intermittent = I and Polymictic = P

Ecoregion:	NLF			CHF			WCP		
Mixing Status:	D	I	P	D	I	P	D	I	P
Percentile value for [TP]									
90%	37	53	57	104	263	344	--	--	284
75%	29	35	39	58	100	161	101	195	211
50%	20	26	29	39	62	89	69	135	141
25%	13	19	19	25	38	50	39	58	97
10%	9	13	12	19	21	32	25	--	69
# of lakes	(257)	(87)	(199)	(152)	(71)	(145)	(4)	(3)	(38)

Lake mixing status was determined for the reference lakes based on summer oxygen and temperature profiles from 1985 and 1986. Lakes were classified as dimictic (stratified throughout summer), polymictic (well-mixed throughout the summer), or intermittent (stratified temporarily throughout the summer). In this analysis most dimictic lakes had maximum depths >10 m, whereas polymictic lakes generally had maximum depths <8 m (Heiskary and Wilson 2005). Maximum depth was used as a basis for estimating mixing status for lakes in the *assessment* database: maximum depth ≥ 11 m = dimictic; maximum depth < 8 m = polymictic; and the remainder were considered intermittent. Frequency distributions of summer-mean TP were assembled for lakes in each of the three categories to evaluate the influence of mixing status (lake morphometry) on lake TP (Table 5). Distinct regional patterns are evident in these data.

In the NLF, differences in TP among the three mixing-status categories are minimal up to the 75th percentile, while in the CHF distinct differences in TP exist among mixing-status categories across the entire range. For example, at the 50th percentile, polymictic lake TP was two- to three-fold higher than the dimictic lakes (Table 5). The TP distribution for intermittent mixing lakes was more similar to the polymictic lakes than the dimictic lakes, and this class was ultimately grouped with the polymictic lakes for criteria setting purposes. Overall, this suggested the need to consider separate criteria for deep (dimictic) and shallow (polymictic and intermittent) lakes in the CHF and WCP ecoregions.

Regional patterns: eutrophication impacts on fisheries

Relationships among lake morphometry, lake water chemistry, and fish yield (Rawson 1952, Ryder 1965, Matusek 1978, Hanson and Leggett 1982) have generally shown that more nutrient-rich, shallower lakes are typically more biologically productive with higher fish yields per unit area than deeper, less fertile lakes. In qualitative terms, a range in fish communities is seen along the productivity continuum ranging from oligotrophic through hypereutrophic. A broad general regional relationship between TP and size and structure of the fish community in lakes was demonstrated by Moyle (1956). To further delineate the connection between TP and fisheries type, approximately 900 lakes of various ecological classification were grouped by ecoregion and the range of TP for each class was determined from the assessment database (Heiskary *et al.* 1987).

Schupp (1992) advanced a new MDNR ecological classification system for Minnesota lakes based on an examination of data from 3,029 lakes. This system takes many physical, chemical, and morphological variables into consideration and results in classifying Minnesota's lakes into 44 types. One of the variables used was Carlson's TSI, based on Secchi transparency. A second division of the lakes was made based on an examination of the distribution of percent littoral with ≥ 80% littoral as an approximate separation of lakes that frequently winter-kill as compared to those <80% that seldom winter-kill.

Schupp (1992) noted distinct relationships among TSI and the presence, relative abundance, and size of several fish species (Fig. 3a–f). Consistent with previous work, he found that when all fish species were considered, a distinct increase occurred in pounds of fish as TSI increased and peaked near a TSI of about 60–65 (Fig. 3a). The number of fish species peaked at a TSI of 40 and remained fairly stable through a TSI of 65; thereafter, a distinct decline in number of species was noted (Fig. 3b). However, as Bachman *et al.* (1996) note in their work on Florida lakes, piscivorous fish declined as a percentage of the total biomass as lakes became more productive (Fig. 3c).

Schupp and Wilson (1993) advanced these concepts further as they compared relative abundance and presence of various fish and water quality (as represented by Secchi-based TSI). For example, the coldwater fishes such as lake trout,

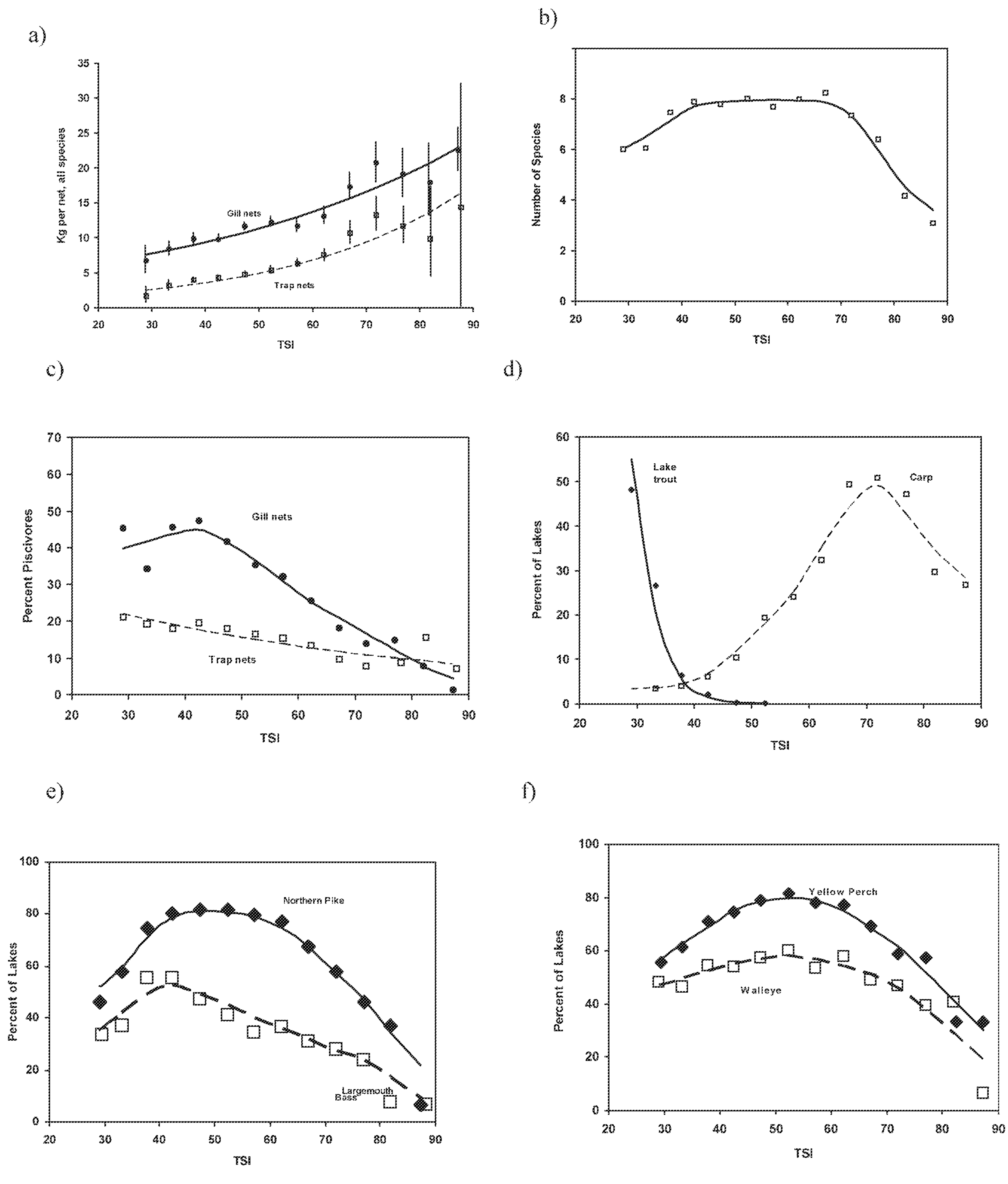

Figure 3.-Relative fish abundance as compared to Secchi transparency-based lake trophic status (TSI). Derived from an analysis of MDNR fisheries records for 3,029 lakes (Schupp 1992). Graphics adapted from Schupp and Wilson (1993) and Schupp unpublished data: (a) fish abundance vs. TSI; (b) number of fish species vs. TSI; (c) percent piscivorous fish vs. TSI; (d) percent of lakes with lake trout and percent of lakes with carp vs. TSI; (e) percent of lakes with northern pike and percent of lakes with largemouth bass vs. TSI; (f) percent of lakes with yellow perch and percent of lakes with walleye vs. TSI.

whitefish, and cisco, exhibit peak abundance over a TSI range of about 30–40 (TP ~ 6–12 µg/L). Lake trout were generally not observed above a TSI of about 45 (TP ~ 17 µg/L; Fig. 3d), while whitefish and cisco are found at TSIs up to about 55–60 (TP ~ 34–48 µg/L). Sight-feeding piscivores such as northern pike and largemouth bass are most abundant at a TSI near 40 (Fig. 3e). While northern pike remain abundant over a TSI range from 40–60 (Secchi 4.0–1.0 m), largemouth bass decline in abundance over that same TSI range. Species such as walleye are abundant across a wide TSI range, peaking over a TSI range of ~ 40–50 (TP ~ 12–24 µg/L) and are most typically found in large mesotrophic lakes, with low clarity and few rooted aquatic plants (Schupp and Wilson 1993). Walleye relative abundance declines as TSI increases from its peak at about 40–50 (Fig. 3f). The relative abundance of common carp increases precipitously over a TSI range of 60–80 as well, with large (step) increases noted as TSI increases from 60–65 (TP~50–70) and again from 70–75 (TP~100–140; Fig. 3d).

Lake trout and stream trout lakes

The environmental requirements for support of lake trout are fairly stringent with respect to DO, temperature, and trophic status, as compared to most warm water species. Dillon *et al.* (2003) define the optimal habitat boundary for lake trout as the portion of the lake having >6 mg/L DO and temperature <10 °C; they acknowledge, however, that some populations can be successful at higher temperatures under some circumstances. Siesennop (2000), in an assessment of Minnesota lake trout lakes, suggests DO concentrations of 6 mg/L and temperatures of ≤ 12 °C as bounds for suitable habitat.

Summer-mean TP, Chl-*a*, Secchi, and DO and temperature profile data were summarized for MDNR-designated lake trout lakes from the *assessment* database. The typical range of values was: TP 9–16 µg/L; Chl-*a* 1.5–3.3 µg/L; and Secchi 4.1–5.8 m (n = 31). In addition, late summer DO and temperature profiles for 15 lake trout lakes were analyzed to determine if there was suitable refuge for lake trout (temperature 8–15 °C and DO > 5 mg/L). Of 15 lakes evaluated, 73% exhibited adequate refuge, 20% were periodically outside this range, and one lake did not exhibit adequate refuge based on the late summer profiles (Heiskary and Wilson 2005). A review of TP and Chl-*a* data for lakes exhibiting adequate refuge suggested that summer-mean TP was generally <15 µg/L (commonly in the 8–10 µg/L range) and Chl-*a* averaged 3 µg/L, with maximum values of 3–4 µg/L or less.

While this analysis does not reveal absolute TP or Chl-*a* thresholds for sustaining lake trout, it suggests that 15 µg/L is probably the upper threshold for summer-mean TP. This value is consistent with the upper range proposed by Nordin (1986) for lake trout lakes in British Columbia and Walker's (1979) analysis that TP exceeding 10–15 µg/L would yield anoxic conditions in the hypolimnion prior to fall turnover. However, it may be high relative to the oft-recognized limit (10 µg/l) between oligotrophic and mesotrophic conditions (Nürnberg 1996). Schupp and Wilson (1993) indicate that the percent of lakes with lake trout declined below 5% at a TSI < 40 (TP = 12 µg/L) (Fig. 3d). Further, it appears that summer-mean Chl-*a* should remain below 3 µg/L, and maximum values should generally remain below about 4 µg/L to minimize the impact of algae (organic matter) on metalimnetic and hypolimnetic DO concentrations. This would be close to the oft-recognized limit between oligotrophy and mesotrophy (3.5 µg/L; Nürnberg 1996).

Trophic status data for 125 stream trout lakes (*i.e.*, stocked trout and splake) was summarized from the *assessment* database. The typical range was TP = 10–21 µg/L; Chl-*a* = 1.9–6.3 µg/L; and Secchi = 3.3–5.4 m. Though temperature and DO requirements for sustaining stream trout are not quite as stringent as lake trout, many of the same principals apply, and the typical range of values was used as the primary basis for setting nutrient criteria for stream trout lakes.

Regional patterns: shallow lakes

Based on the *reference* and *assessment* databases, some distinct differences emerge in trophic status and potentials of shallow, well-mixed lakes as compared to deep, stratified lakes (Tables 4 and 5). These differences are apparent to lake users as well. During public hearings, associated with the establishment of MPCA guidance (MPCA 2007) for assessing nutrient-impaired lakes for Clean Water Act (CWA) Section 303(d) listing, concerns were expressed by several respondents that swimming may not be the primary use in many of Minnesota's shallow lakes. Among their contentions were: the shallowness of the lakes, highly organic substrates, and often times over-abundance of rooted submergent and emergent plants. Because of these factors, several respondents recommended that the MPCA consider separate nutrient criteria for shallow lakes that would take these factors into account.

These observations prompted further study of shallow lakes. Because differences in trophic status were particularly marked among deep and shallow lakes of the CHF and WCP ecoregions (Table 5) and the high percentage of shallow lakes in these regions, further study focused on these regions. For purposes of selecting study lakes and rulemaking, shallow lakes were defined as (based largely on Schupp 1992) "lakes with a maximum depth of 15 feet (4.5 m) or less or where 80% or more of the lake is littoral (portion of the lake 15 feet or less)."

The *west-central shallow lakes study* was based on the concept of "alternative states" as described by Moss *et al.* (1996), Moss (1998) and numerous others, whereby shallow lakes

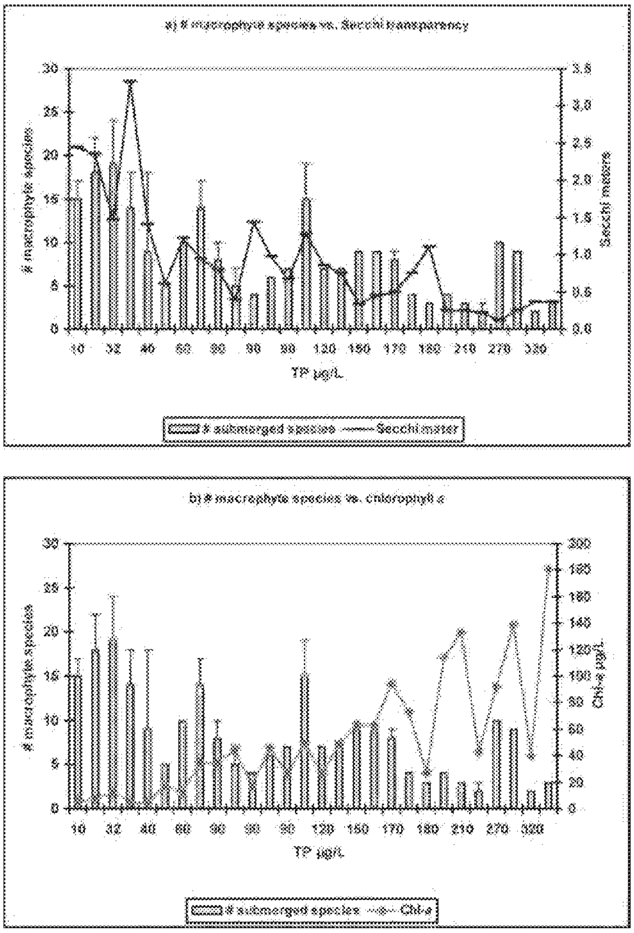

Figure 4.-Comparison among number of species of submerged (solid bar) and floating leaf macrophytes (depicted by "error bar") relative to: (a) summer-mean Secchi transparency and (b) summer-mean chlorophyll *a* based on 27 shallow west-central MN lakes. Lakes sorted by summer-mean TP. Submerged plus floating-leaf equals total number of macrophyte species present in each lake.

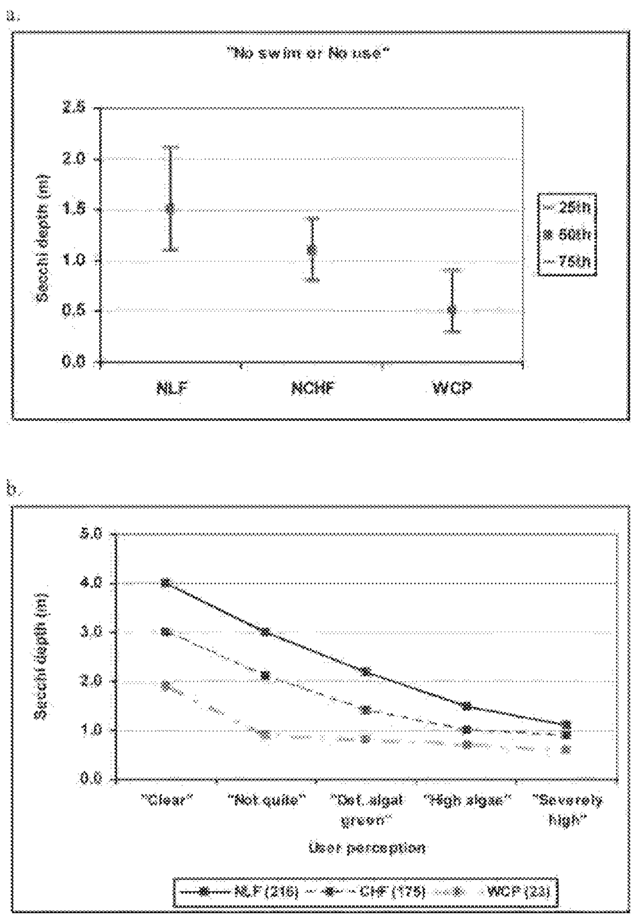

Figure 5.-User perception relative to Secchi transparency by ecoregion: (a) interquartile range corresponding to perception of "no swimming" or "no use." (drawn from Heiskary and Walker 1988) and (b) geometric mean Secchi transparency relative to user perception of physical appearance (drawn from Smeltzer and Heiskary 1990). Number of observations in parenthesis. See Table 6 for further description of condition ratings.

may switch from relatively clear plant-dominated systems at low nutrient concentrations to cloudy, algal-dominated systems at high nutrient concentrations. While exact thresholds are not frequently noted, several studies suggest inverse relationships among macrophyte coverage and phytoplankton Chl-*a* and resuspension of sediment and TP in shallow lakes (Portielje and Van der Molen 1999, Madsen *et al.* 2001, Scheffer *et al.* 2001). Most studies agree that shallow lake response to excess nutrient loading is not linear; rather, the lake may be stable until a threshold is reached and then an alternate stable state is reached. To switch back, one must reduce nutrients to a much lower level than it was previously to some "critical" level. With this in mind, we sought to identify thresholds that might minimize the risk of shallow lakes shifting from a macrophyte-dominated state to an algal-dominated state.

Macrophyte populations were assessed for the lakes and metrics reflective of ecological integrity; for example, the number of species of submerged aquatic vegetation (SAV), number of species of floating-leaf plants, and Floristic Quality Index (FQI) were compiled for each lake. These data, when combined with trophic status data, provided an opportunity to identify potential thresholds for establishing nutrient criteria for shallow lakes (Fig. 4a and 4b). Some fairly distinct patterns are evident from this work that suggest that as TP increases above 60–90 µg/L, a decline occurs in FQI, SAV, and floating-leaf species, and a concomitant increase in algal dominance and decrease in transparency (Heiskary and Lindon 2005). These and related observations provided a basis for defining appropriate TP, Chl-*a*, and Secchi thresholds for shallow lakes.

Table 6.-Lake Observer Survey (Garrison and Smeltzer 1987). Citizen volunteers and monitoring staff use this subjective scale to rank recreational suitability and physical condition of the lake at the time and place of the sampling.

A. Please circle the one number that best describes the physical condition of the lake water today:

1. Crystal clear water.
2. Not quite crystal clear, a little algae present/visible.
3. Definite algal green, yellow, or brown color apparent.
4. High algal levels with limited clarity and/or mild odor apparent.
5. Severely high algae levels with one or more of the following: massive floating scums on lake of washed up on shore, strong foul odor, or fish kill.

B. Please circle the one number that best describes your opinion on how suitable the lake water is for recreation and aesthetic enjoyment today:

1. Beautiful, could not be any nicer.
2. Very minor aesthetic problems; excellent for swimming, boating, enjoyment.
3. Swimming and aesthetic enjoyment slightly impaired because of algae levels.
4. Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels (would not swim, but boating is okay).
5. Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels.

Regional patterns: user expectations

Definitions of "acceptable" or "objectionable" lake water quality vary regionally (Heiskary and Walker 1988). A lake user in a region dominated by oligotrophic lakes would probably have much higher expectations (*e.g.*, higher transparency and lower algal levels) as compared with a lake user in a region dominated by hypereutrophic lakes. Defining the relationship between user expectations and lake water quality measurements is an important part of the criteria setting process. A methodology for deriving this information is presented in greater detail in Heiskary and Walker (1988). Basically, the methodology involves cross-tabulating water quality measurements against observer survey categories (Table 6), which provides a basis for calibrating nuisance criteria on a statewide and regional basis.

Following their introduction in 1987, user perception surveys have become a routine aspect of data collected by citizen volunteers in Minnesota and other states (*e.g.*, Vermont and New York). Several papers have been published on the use of this type of information in criteria development in Minnesota (*e.g.*, Heiskary and Walker 1988), comparing user perceptions across ecoregions and two states (Smeltzer and Heiskary 1990), and a more recent effort to assess user perception across several USEPA nutrient ecoregions and states (NYFLA 2003). Likewise, the use of user survey data as one basis for criteria development has been supported in USEPA guidance (USEPA 2000d).

Regional differences in user perception are evident for Minnesota. Heiskary and Wilson (1989) noted that lake users in the NLF ecoregion have high expectations regarding water quality. For example, in 75% of the observations ranked as "impaired" or "no swimming" or "high or severe algae," the corresponding Secchi reading was 2.0 m or less (Fig. 5a). In the CHF ecoregion 75% of the observations in these categories were associated with Secchi readings of 1.4 m or less, while in the WCP ecoregion 75% of the observations in these categories were associated with Secchi readings of 0.9 m or less. In a more data-intensive effort, Smeltzer and Heiskary (1990) examined user perception responses for three Minnesota ecoregions (NLF, CHF, and WCP combined with the NGP), Vermont's inland lakes, and Lake Champlain. A prominent finding (as it relates to criteria development) was that for Minnesota, Secchi values for the NLF were generally higher for a given response than in the other regions, and regional differences were especially pronounced at the lower end of the survey scale (*i.e.*, responses of "crystal clear" and "beautiful, could not be any nicer"; Figure 5b). Differences among regions and survey response were statistically significant (Smeltzer and Heiskary 1990). Results from this study reaffirmed regional patterns noted in earlier work (Heiskary and Wilson 1989) and represent one basis for establishing criteria.

Regional patterns: sediment diatom-inferred TP

Lake-sediment cores provide a valuable archive of information over a historical continuum of water quality and related environmental factors. Distinct differences among regions were evident in comparisons of pre-European and modern-day TP concentrations. For the NLF lakes as a group, there was no significant difference in pre-European versus modern-day TP (Fig. 6). However, significant increases in TP were noted for the CHF lakes (Fig. 6), and these increases exceeded the "natural variability" noted in comparisons with pre-European (1750 and 1800) TP concentrations (Ramstack *et al.* 2004). The degree of change in TP among the Twin Cities seven county metropolitan (Metro) area CHF lakes is significantly correlated with the percent of the watershed in urbanized landuse, while those in the rural portion exhibit a significant correlation with the percent of landuse in agricultural uses, or inversely the percent in forested uses. Increases from pre-European to modern-day for the Metro lakes were rather minimal (as a group); however, the rural lakes exhibited a significant increase based on comparison of means ± standard error. The deeper dimictic WCP lakes also did not change significantly across the two time periods (pre-European and modern-day). No significant associations with landuse were noted by Ramstack *et al.* (2004), presumably because of the small sample size (5 lakes) and the predominately agricultural landuse in these watersheds. However, these five lakes had the highest modern-day TP of any of the lakes in the 55 Lakes Study and as such were at the fringe of the data used to construct the predictive model.

Data from the 55 Lakes Study was pooled with the Southwest and West-Central Shallow Lakes Studies to provide a more robust estimate of historical shallow lake conditions. The resulting 79 lakes model exhibited a significant modern-day TP increase relative to pre-European values for shallow lakes (Fig. 6). It was also evident that pre-European TP in shallow CHF and WCP lakes was higher than their deeper counterparts and was a confirmation of the need for development of separate shallow lakes criteria.

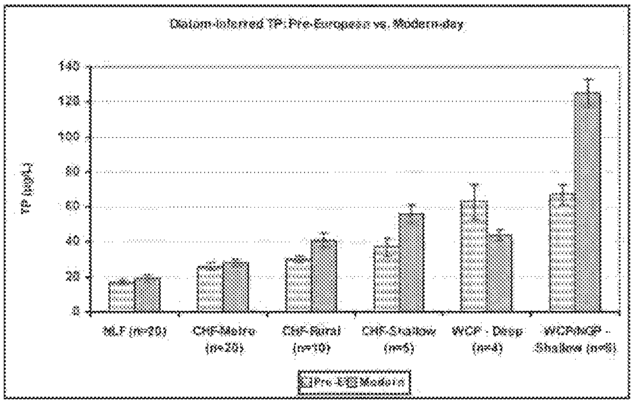

Figure 6.-Mean diatom-inferred total phosphorus. Comparison of pre-European (pre-E) vs. modern-day by ecoregion. Standard error of the mean and number of lakes for each group noted. Means are not significantly different when mean ± standard error overlap with another mean ± standard error.

Discussion

Deriving eutrophication criteria-general considerations

Minnesota's approach to criteria development employs the aforementioned databases, research efforts, and associated literature review. The approach does not differ substantially from that previously described in Heiskary and Walker (1988) and Heiskary and Wilson (1989). It is best described as a "weight-of-evidence" approach that acknowledges differing uses and potentials of lakes (Table 1). Weight of evidence, as used in this context, is the collective summary of scientific information pertaining to identifiable lake response thresholds, linked with the most sensitive beneficial uses, attuned to regional and lake-type distinctions, and coupled with user perceptions of water quality.

The initial focus of these databases and research findings is on the typical (interquartile) range of the data and examples for TP (Fig. 7a–c). Secondly, the most sensitive sub-uses of lakes in each region are used as a basis for developing ecoregion-specific criteria for TP, Chl-*a*, and Secchi. The following considerations and relevant data are considered prominently in developing the criteria:

- Typical trophic status range of the *reference lake* data represents a starting point for establishing criteria, with an initial focus on TP. Emphasis is placed on the 75th percentile of the reference population; however, this is not the sole consideration, and the actual percentile may vary among regions.
- The typical range for the MPCA and EPA *assessment* databases are considered, focusing on the 25th to 50th percentiles.
- Pre-European (diatom-inferred) TP concentrations provide perspective on pre-settlement natural background condition and what might be considered the lowest achievable TP for each ecoregion. The 75th percentile is used for this purpose.
- Following establishment of some target ranges based on TP, the analysis is extended to Chl-*a* and Secchi, and similar comparisons among the *reference* and *assessment* databases are made. Linkages among TP, Chl-*a*, and Secchi are made based on lake response regressions using, for example, Carlson's TSI (Carlson, 1977) and Eq. 1–3. Further linkages are made to nuisance bloom frequency and extreme conditions as it relates to summer-mean TP (Fig. 2a and 2b) and Chl-*a* (Eq. 4).
- User perceptions of recreational suitability are paired with Secchi transparency and Chl-*a* to statistically define "swimmable" conditions (Fig. 5a and 5b). A primary focus is on minimizing the occurrence of con-

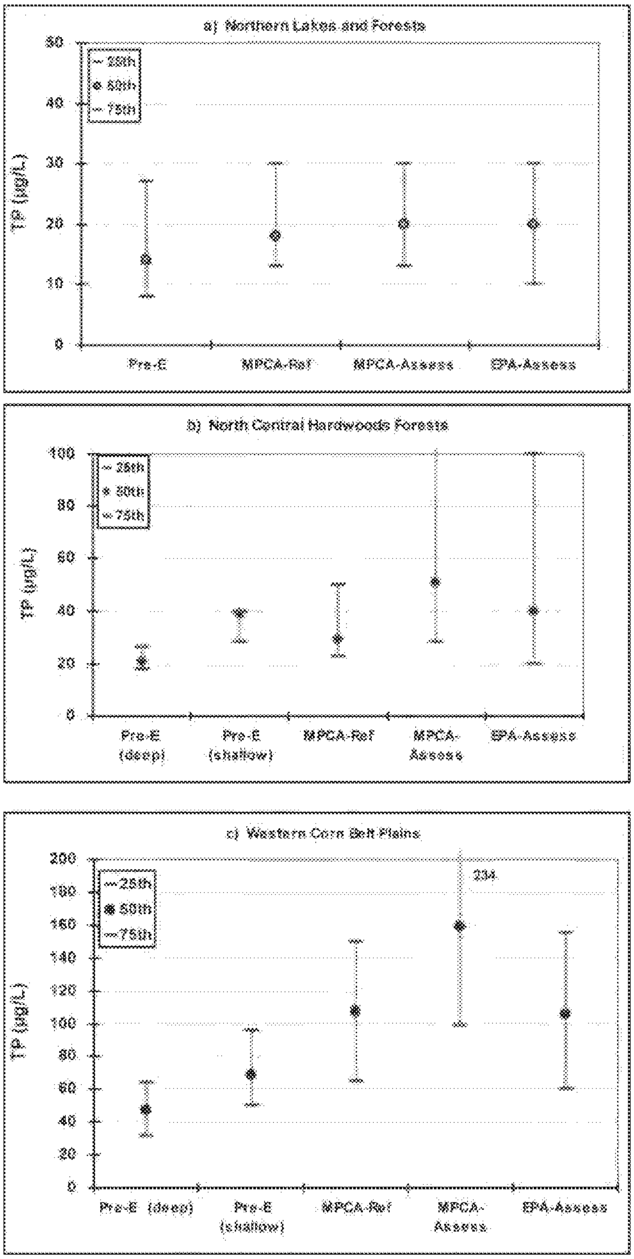

Figure 7.-Comparison of summer-mean total phosphorus interquartile ranges for: diatom-inferred pre-European (pre-E), reference, and assessment databases for (a) Northern Lakes and Forests (NLF), (b) North Central Hardwoods Forests (CHF) and (c) Western Corn Belt Plains (WCP) ecoregions.

ditions characterized as "swimming impaired" or "high algae" in the NLF and CHF ecoregions. In the WCP and NGP ecoregions, minimizing the occurrence of conditions characterized as "no swimming" or "severe algal blooms" is the primary emphasis. As thresholds are identified, the interrelationships of TP, Chl-*a*, and Secchi are used to further refine proposed criteria ranges as a part of the weight-of-evidence approach.

- For MDNR-designated lake trout lakes, data from assessed lakes and interrelationships among TP, Chl-*a*, Secchi, and hypolimnetic oxygen depletion (HOD) are the primary bases for criteria development. For MDNR-designated stream trout lakes HOD is not as significant of a concern, and data from assessed stream trout lakes is a primary basis for criteria establishment, with a focus on values near the 75th percentile. As for other fish populations, established relationships among lake TSI and select species provide a further basis for refining criteria ranges (Fig. 3a–f).
- Shallow lake criteria are developed for the CHF and WCP ecoregions with an emphasis on ecological endpoints in contrast to swimmable-use endpoints, which is a primary focus in deep lakes. Linkages among trophic status measures and rooted macrophyte metrics are a primary basis for recommending criteria ranges (Fig. 4a and 4b).

Ecoregion-specific criteria development: North Central Hardwood Forests

An ecoregion example can be used to demonstrate the above process and employment of considerations. The CHF ecoregion was chosen for its diversity of "most sensitive uses," including stream trout lakes, aquatic recreational use, and shallow lakes (Table 1).

Fisheries: stream trout lakes

The CHF ecoregion contains no natural lake trout lakes and very few stream trout lakes. Criteria recommendations for stream trout lakes relied heavily on an analysis of pooled data from stream trout lakes in the NLF and CHF ecoregions. The initial focus was on the distribution of TP values from these lakes, and the 75th percentile was chosen as an appropriate level for establishing the criteria. Similar analysis was done for Chl-*a* and Secchi, and their typical ranges were noted. Chlorophyll *a* and Secchi criteria were selected based on these distributions and refined to correspond to the TP criterion based on interrelationships defined in Eq. 1–3. In this instance, there was no ecoregion-based difference in the recommended criteria because supporting this use required relatively low trophic status, and a case for ecoregion-based differences could not be made.

Aquatic recreational use: deep lakes

The MPCA and EPA *assessment* databases exhibit very similar TP and IQ ranges (Fig. 7a), with an overall range of 84 and 80 µg/L, respectively. This large range is a function of the heterogeneity of the lakes in this region (*e.g.*, morphometry, watershed characteristics, and anthropogenic impacts). The *reference* database exhibits a much smaller IQ range (27 µg/L) than the *assessment* database. Comparison of the 25th percentile for the MPCA and EPA *assessment* and the 75th percentile for the *reference* databases (Fig. 7b) suggests an appropriate TP criteria level is between 20 and 28 µg/L (25th percentile *assessment*) and 50 µg/L (75th percentile *reference*). Further, the 25th percentiles for the *reference* and *assessment* databases correspond to about the 75th percentile for the "deep" pre-European diatom-inferred TP concentrations.

Based on the above, 40 µg/L was recommended as the TP criteria for deep recreational lakes. At or below 40 µg/L, "severe nuisance blooms" should occur less than 5% of the summer and "nuisance blooms" should occur less than 20% of the summer (Fig. 2a.). Secchi transparency should remain greater than 1.0 m over 90% of the summer (Heiskary and Walker 1988) and minimize the likelihood of conditions deemed "no swimming" or "high algae" (Fig. 5a and 5b). Also as TP increases above about 40–50 µg/L (TSIs of about 55–60), the number of piscivores start to decline, and relative abundance of carp and black bullhead tend to increase (Fig. 3c and 3d).

Aquatic recreational use: shallow lakes

The CHF ecoregion has a large number of shallow lakes that represent a significant percentage of total lakes in the region (~40%; Heiskary and Wilson 2005). Healthy shallow lakes are often characterized by diverse populations of macrophytes over much of the basin. As such, maintaining adequate transparency to allow establishment of rooted macrophytes over much of the basin, minimizing the occurrence of nuisance algal blooms, and keeping TP concentrations below a range that promotes excessive algal growth are all important considerations for setting base eutrophication criteria. Of these three variables, transparency may be the most important. In turn, transparency can be directly related to TP and Chl-*a* (Eq. 2 and 3), although several biotic factors, such as dominance of benthivorous (*e.g.*, carp and bullhead) or planktivorous fish, and abiotic factors, such as suspended sediments, lake depth, wind erosion, and resuspension, may also influence transparency and the ability of the lake to support macrophytes.

Transparency should remain above about 0.7 m and ideally 1.0 m or greater to minimize the likelihood of a reduced number of SAV and floating-leaf species (≤ 10 species; Fig. 4a) or low Floristic Quality Index (FQI; Heiskary and Lindon 2005). A summer-mean transparency of 0.7–1.0 m should allow SAV colonization to a depth of about 1.5–2.0 m based on equations developed by Canfield *et al.* (1985) and Chambers and Kalff (1985) and data from the west-central Minnesota lakes (Heiskary and Lindon 2005). This represents an appreciable portion of a typical shallow lake where mean depths are often 1–3 m (Heiskary and Lindon 2005) and should allow for macrophyte dominance over much of the lake.

The corresponding TP range to yield a transparency of 0.7–1.0 m is around 48–68 µg/L based on Carlson's TSI and about 60–80 µg/L based on Eq. 3. Total P concentrations >60–80 µg/L are undesirable because the frequency of severe nuisance blooms increases substantially (Fig. 2b) and the number of macrophyte species declines, which often signals a shift to a turbid algal-dominated system (Fig. 4b). Given this range of values, and acknowledging that other biotic and abiotic factors can be significant in determining whether a lake can support a healthy and diverse population of rooted macrophytes, we recommended that the criteria be set at the conservative end of each range of the aforementioned values for summer averages: Secchi of 1.0 m or greater; Chl-*a* of 20 µg/L or lower; and TP of 60 µg/L or lower. Maintaining values in this range will not absolutely ensure that a shallow lake will remain in a plant-dominated state but should reduce the risk that the lake will switch to an algal-dominated state, which as repeatedly noted in the literature can be difficult to reverse once the change has occurred.

Summary

Ecoregion-specific eutrophication criteria have been developed for Minnesota's lakes and include criteria for the "causative" variable TP and the two "response" variables Chl-*a* and Secchi (Table 1). The criteria were based on detailed analysis of several databases, including *assessment*, *reference*, *diatom-inferred*, and *USEPA criteria* databases. Understanding regional patterns and interrelationships among TP, Chl-*a*, and Secchi based on these databases, fisheries information, user perception, and other information was critical to criteria development. Designated uses of the lakes were considered, and appropriate linkages to existing water quality standards classifications were made. This approach is best described as a "weight-of-evidence" approach and is consistent with much of what is shared in USEPA guidance (USEPA 2000d).

Following adoption of these criteria into Minnesota's water quality standards, they will serve as the primary basis for assessing the condition of Minnesota's lakes. One application of the criteria will be to determine which lakes have excessive TP and algal concentrations and should be deemed as "impaired" as a part of the CWA Section 303(d) impaired waters assessment that states are required to conduct. In this context a lake must exceed the causative variable (TP) and one of the response variables to be deemed "impaired" for purposes of 303(d) assessment. More broadly, the criteria will provide a basis for improved lake management covering the spectrum from prioritizing monitoring efforts, supporting lake protection efforts, and establishing meaningful endpoints for lake rehabilitation.

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Biochemical Oxygen Demand and Algae: Fractionation of Phytoplankton and Nonphytoplankton Respiration in a Large River

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Mass balance equations for dissolved oxygen in streams are formulated to account for, among other variables, algal respiration (R), and biochemical oxygen demand (BOD). The oxygen consumption measured in primary productivity-respiration analyses is not R but is total community oxygen consumption (TCOC), and BOD measurements are complicated by undefined algal components. Ultimate BOD was found to be 0.24 mg of O_2 consumed per μg chlorophyll a and carbonaceous BOD was 0.20 per μg chlorophyll a in excess of background BOD. The results were similar for live and dead algae. Phytoplankton respiration was fractionated from nonphytoplankton oxygen consumption (NPOC) by the regression of respiration against chlorophyll a to obtain a y intercept of zero chlorophyll. The intercepts, NPOC, closely matched O_2 consumption measured when phytoplankton biomass was very low. Phytoplankton respiration, calculated as the residual of the difference between TCOC and NPOC, ranged from 0.2 to 1.5 (mean = 0.88) mg O_2 per mg chlorophyll a per hour, close to the literature value of 1 (in cultures). Depth-integrated (DI) phytoplankton respiration was 1/4 to 1/3 of DI gross primary productivity and 1–3% of maximum primary productivity. The separation of phytoplankton R and NPOC permitted the demonstration that R probably is not a simple function of productivity.

INTRODUCTION

The *Streeter and Phelps* [1925] first-order, partial differential equation model describing the mass balance of dissolved oxygen (DO) has evolved in several paths. One of the early improvements was the addition of several sources and sinks to the simple reaeration and biochemical oxygen demand (BOD) model [e.g., *Thomas*, 1948; *Dobbins*, 1964]. Perhaps the most complex and least understood of these sources and sinks are photosynthetic oxygen production (or primary productivity) P and algal respiratory consumption R.

If longitudinal dispersion is negligible and the atmosphere, BOD, and phytoplankton are the only sources and sinks of DO, then the mass balance equation takes the form

$$\frac{\partial C}{\partial t} + \frac{1}{A}\frac{(Qc)}{\partial x} = K_a(C_s - C) - K_d L_0 + (P(t) - R(t)) \qquad (1)$$

[*O'Connor and DiToro*, 1970], where

- C concentration of dissolved oxygen (M/L^3);
- t time (T);
- A area (L^2);
- Q discharge (L^3/T);
- x distance (L);
- K_a atmospheric reaeration coefficient (T^{-1});
- C_s DO saturation concentration (M/L^3);
- K_d decay coefficient for BOD (T^{-1});
- L_0 ultimate carbonaceous BOD (M/L^3);
- $P(t)$ rate of primary productivity per area ($M/L^3/T$);
- $R(t)$ rate of algal respiration per area ($M/L^3/T$).

As early as the 1920s, *Streeter* [1922] recognized the importance of the ($P - R$) term, although according to *Erdmann* [1979], some still choose to ignore it even though benthic and phytoplankton algae may contribute significantly to the DO mass balance. The measurement of P and R is time and labor intensive. Researchers therefore have presented solutions to the DO mass balance equations by substitution of empirical, time variable functions for ($P - R$), i.e., cosine functions of time [*Hansen and Frankel*, 1965], Fourier series [*O'Connor and DiToro*, 1970], time constant production [*Koivo and Phillips*, 1971], piecewise linearization [*Hornberger and Kelly*, 1972], and convolution integrals [*Bennett*, 1971]. The parameters defining these productivity equations often are obtained from primary productivity and respiration measurements made in the field. As *Thomann* [1972, p. 107] suggests, "Unfortunately, there is no direct method of obtaining estimates of respiration due to algae alone, independent of bacterial respiration." Respiration measured in dark bottles or at night is total community oxygen consumption (bacteria, zooplankton, algae, and nitrification). Therefore the ($P - R$) term is not a simple net primary productivity. There have been attempts to fractionate algal and nonalgal respiration [*Hargrave*, 1969; *Ganf*, 1974; *Ganf and Blazka*, 1974; *Lewis*, 1974]. The successes and results of these studies have been variable.

Similarly, the $K_d L_0$ term for the water column is not solely due to microbial oxidation of organic matter. As noted by *Fitzgerald* [1964], algal respiration in the dark and algal death followed by oxidation during BOD tests can make BOD data difficult to interpret. Thus, using current methods to solve the DO mass balance equation results in what may be considered a double accounting of BOD and algal oxygen consumption: both make undefined contributions to the water column $K_d L_0$ and R terms in equation (1).

There are three objectives of this paper: (1) to demonstrate the effect of algae (live and dead) on water column (not benthic) BOD, (2) to separate phytoplankton from nonphytoplankton oxygen consumption (NPOC) during the low-flow July–August period in the fresh, tidal Potomac River, and (3) to examine the relationship of phytoplankton respiration (as established in objective 2) to primary productivity.

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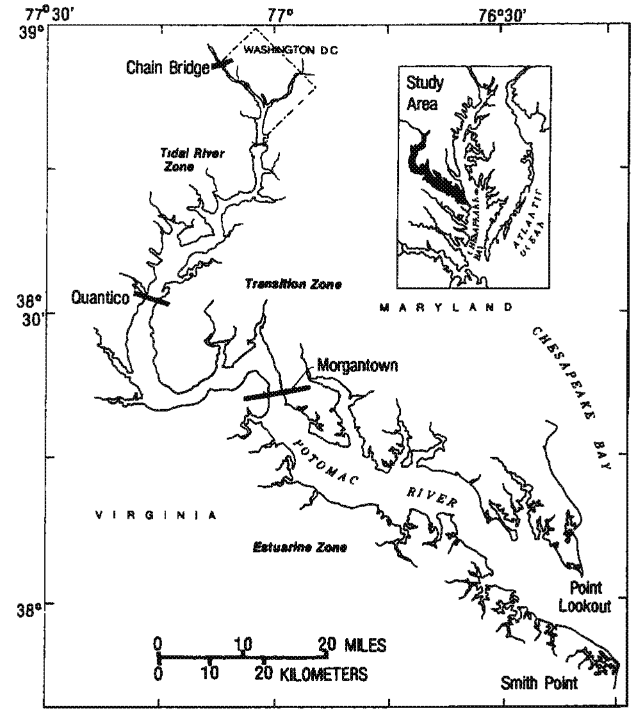

Fig. 1*a*. Tidal Potomac River and estuary. Shaded area is the transition zone between the fresh, tidal river, and brackish estuary. Thick lines delineate approximate boundaries of zones.

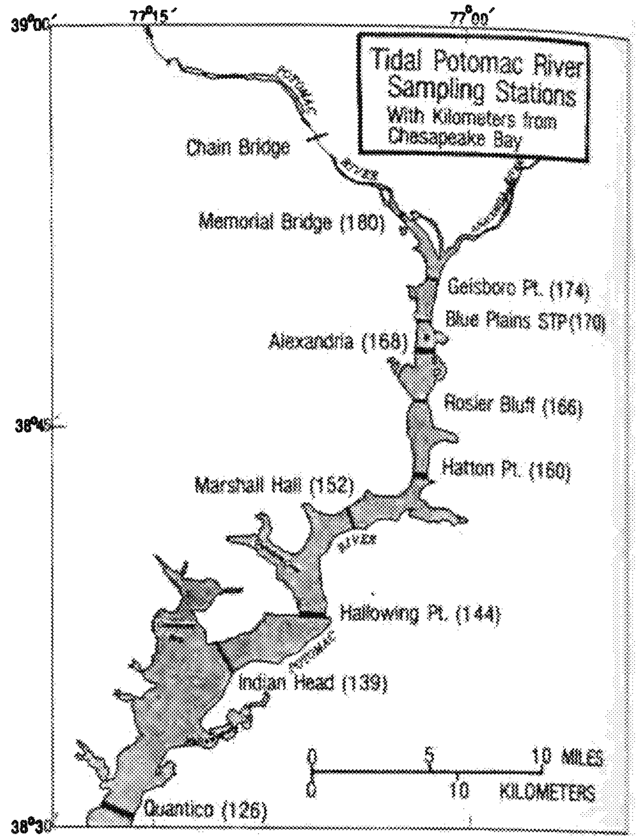

Fig. 1*b*. The fresh, tidal Potomac River. Alexandria 1 is in the main channel; Alexandria 2 is a small channel adjacent to the Maryland shore into which much of the Blue Plains STP effluent is discharged.

Several assumptions are made in this paper. It is assumed that day to day changes in temperature during July and August have little effect on microbial and phytoplankton metabolic activity. Waste loading is assumed to be constant during each summer. Thus NPOC should be approximately constant if discharge is steady. In fact, the volume of waste discharge was 20 m^3 s^{-1} for each of July and August 1980 with ultimate BOD (UBOD) being 1263 metric tons (t) in July and 1162 (t) in August (data from *Coupe and Webb* [1984]). The corresponding values for 1981 were 20 m^3 s^{-1} in July and 19 m^3 s^{-1} in August and 666 t in July and 693 in August. In determining depth-integrated (areal) respiration, it is assumed that respiration is constant with depth (and therefore light). There is considerable evidence that respiration varies with light and depth [*Gibson*, 1975; *Stone and Ganf*, 1981]. Phytoplankton respiration also may be repressed in the light [*Harris and Piccinin*, 1977] or may be similar to levels in the dark [*Bidwell*, 1977]. There is not enough evidence to disprove any of these alternatives, and the relationships are not well enough defined to establish a model of respiration and depth that would displace an assumption of constancy with depth.

The research was done as part of an interdisciplinary study of the tidal, fresh Potomac River. The tidal Potomac River and estuary, Maryland, extends 187 km from above Washington, D. C., at Chain Bridge to the Chesapeake Bay (Figure 1*a*). The tidal freshwater reach, approximately 62 km long, has a volume of 3.4×10^8 m^3 and receives drainage from the nontidal Potomac River and metropolitan Washington, D. C. It has an average flow of 310 m^3 s^{-1} and receives approximately 1.4×10^6 m^3 per day of treated waste water from municipal treatment facilities. During the summer, a zone of high phytoplankton concentration extends from river km 180 at Memorial Bridge to km 126 at Quantico, Virginia, the approximate, late summer location of the brackish-freshwater interface (Figure 1*a*).

Sampling stations for productivity and respiration analysis are listed in Table 1 (with the depth used to calculate depth-integrated productivity) and shown in Figure 1*b*. River distances are measured from the center of a line drawn between Smith Point and Point Lookout at the mouth of the Potomac River.

METHODS

A light and dark bottle oxygen method for determining phytoplankton productivity similar to that described by

TABLE 1. Sampling Stations for Productivity and Respiration Analysis

Station	River Distance From Chesapeake Bay, km	Average Depth, m
Potomac River at Alexandria, Virginia (Alexandria 1) (in the channel near the Virginia shoreline)	168	2.2
Potomac River across from Alexandria, Virginia, near Maryland shoreline (Alexandria 2)	168	2.8
Potomac River at Hatton Point, Maryland	160	3.9
Potomac River at Hallowing Point, Virginia	144	5.6

Greeson et al. [1977] was used. Depth-integrated samples for productivity analyses initially were collected with an open, weighted, 4-L, polyethylene bottle fitted with a vent tube. The bottle was filled as it was lowered and raised in the water column at a uniform rate. From August 1980 through September 1981, samples were collected through a centrifugal pump and hose. There was no significant difference in productivity and respiration between pumped and bottle samples [*Cohen and Pollock*, 1983]. Samples were composited until a 20-L, polyethylene carboy was filled. Clear and opaque, black, 300-mL BOD bottles were filled by siphon from the 20-L bottle. Samples were collected during the evening (between 1700 and 2100 hours) and incubated overnight and throughout the next day, for a total of 24 hours. Dissolved oxygen was measured at the beginning and end of the incubation with an Orbisphere polarographic oxygen probe; the BOD bottles then were then sealed. If degassing due to supersaturation became apparent, the incubations were terminated about midday. Bottles were placed in 92-cm-wide by 122-cm-long by 15-cm-high wooden boxes. The boxes were filled to overflowing and flushed continuously with river water by submersible pumps. Thus the bottles were maintained at in situ river temperatures. One section of the box was exposed to full surface sunlight. The other sections were covered by one, two, three, or five layers of nylon screen transmitting 65, 32, 16, and 6% surface light, respectively. Three clear bottles were placed in full sunlight, and two were placed in box sections exposed to 65, 32, 16, and 6% of full sunlight. Five black bottles were placed under the five layers of screen. Bottles were shaken and rotated every hour to eliminate artifacts due to settling phytoplankton and sediment. Samples for chlorophyll *a* analysis were taken at the beginning and end of incubations. A detailed description of the methods for determining respiration and primary productivity is given by *Cohen and Pollock* [1983].

Dawn to dusk, 4-hour and 2-hour, midday productivity incubations sometimes have been recommended to minimize "bottle effects" [*Vollenweider*, 1965]. However, nutrient-limitation bioassays were performed simultaneously with the respiration and productivity experiments [*Cohen and Pollock*, 1983], and nutrients must be added during the evening to demonstrate any significant stimulation during the next day [*Stross*, 1980; *Lean and Pick*, 1981]. Long-term incubations (24 hours or more) give reliable results (which are sometimes underestimates) if algae populations remain healthy [*Lean and Pick*, 1981].

Light intensity was measured along with productivity and respiration so that a maximum rate of productivity ($P_{\max}$) could be calculated. The parameter $P_{\max}$ was determined using the familiar, simple equation analogous to the *Monod* [1942] hyperbolic function that describes the relationship of productivity to light intensity [*Lederman and Tett*, 1981],

$$P = P_{\max} \frac{I}{I + K_m}$$

where I is light intensity, in microeinsteins per square meter per day and K_m is light intensity at which $P = 0.5\ P_{\max}$. A nonlinear, least squares, parameter estimation technique [*Bard*, 1974] was used to fit the productivity-light equation to the data of each productivity experiment and to estimate $P_{\max}$.

Samples for the BOD experiments were taken from the fresh, tidal Potomac River in February 1981 to minimize the number of phytoplankton present. Subsamples were filtered through a 63-μm mesh net to remove zooplankton. These are referred to as "filtered" samples. BOD experiments were performed in conjunction with W. E. Webb of the U.S. Geological Survey Potomac River Quality Assessment.

Biochemical oxygen demand (BOD) values were determined by fitting the model $L = L_0(1 - e^{-kt})$ to 8–15 polarographic oxygen measurements over 20 days, where L is BOD at time T, in days; L_0 is ultimate demand; and K_1 is rate, per day. Subsamples were inhibited with TCMP (2 chloro-6) (Trichloromethyl) (1-Allyl-2-thiourea) pyridine. Carbonaceous BOD (CBOD) and ultimate BOD (UBOD) were calculated based on the results of noninhibited samples (see *Coupe and Webb* [1984] for methodological details).

Algae used for the BOD-algae experiments were *Chlamydomonas reinhardi* obtained from the American Type Culture Collection, Rockville, Maryland. They were grown for 2 weeks in an aerated, freshwater modification of F/2 medium [*Guillard and Ryther*, 1962; *McLachlan*, 1973]. Aliquots of concentrated live *Chlamydomonas* were added to 300-mL BOD bottles and chlorophyll *a* was measured in a subsample. Clumping of algae in cultures made it impossible to add identical quantities of organisms to each BOD sample.

Other aliquots were sonicated, then quick frozen over dry ice. These samples were examined under an inverted microscope at 400x to determine viability. Dead algae were added to BOD bottles and pigment concentrations were measured. Chlorophyll *a* and phaeophyton *a* were determined by the *Holm-Hansen and Riemann* [1978] modification of the *Strickland and Parsons* [1972] method.

RESULTS

BOD-Algae Experiments

Chlorophyll *a* concentrations in the water column samples (controls) were 5 $\mu g\ L^{-1}$ unfiltered and 6.5 $\mu g\ L^{-1}$ after filtration through a 63-μm mesh net to remove zooplankton. The difference between the two water column samples is probably due to sample variance and not due to removal of zooplankton. Chlorophyll *a* concentrations, measured after addition of *Chlamydomonas reinhardi* to experimental samples were (1) 208 $\mu g\ L^{-1}$ for unfiltered samples with dead algae added; (2) 252 $\mu g\ L^{-1}$ for unfiltered samples with live algae added; (3) 222 $\mu g\ L^{-1}$ for filtered samples with dead algae added; and (4) 270 $\mu g\ L^{-1}$ for filtered samples with live algae added. The CBOD of samples with live algae were similar (within 10%) to those with dead algae and both were more than 100% higher than controls (Figure 2). UBOD also was similar for live and dead algae samples and was more than 100% higher than controls (Figure 2). The algae became scenescent and died quickly; their chlorophyll degraded to phaeopigment by day 3 of the incubations and there was a reduction of 90% of combined chlorophyll and phaeopigment by day 20 (Figure 3).

CBOD and UBOD were proportional to the chlorophyll biomass added to the raw samples (Figure 4). CBOD was 0.20 and UBOD was 0.24 mg BOD L^{-1} per μg chlorophyll *a* L^{-1}. The nutrient media used for the culture of *C. reinhardi* had no effect on the CBOD (both were 3.2 mg BOD L^{-1}) and little effect on UBOD (4.3 mg BOD L^{-1}, standard deviation

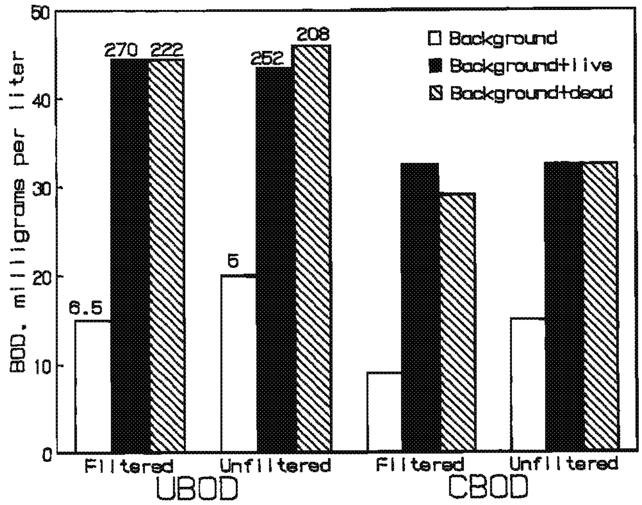

Fig. 2. The effect of live and dead algae on UBOD and CBOD. Filtered samples were poured through 63-μm mesh net to remove zooplankton from the background (control) samples. The numbers above the bars are $\mu g\ L^{-1}$ chlorophyll *a*.

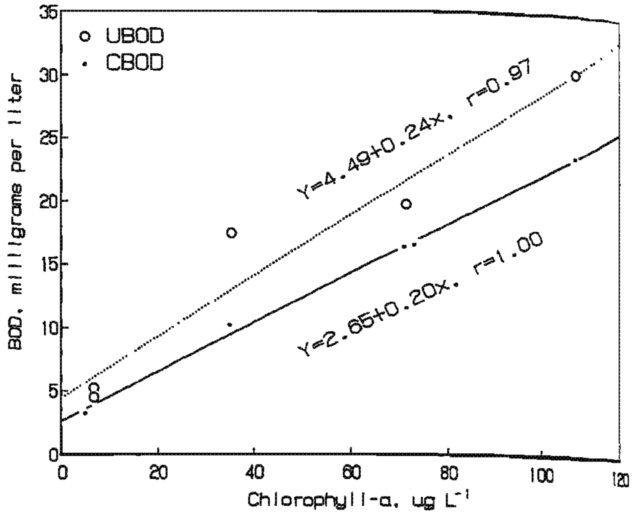

Fig. 4. Regressions of UBOD and CBOD against chlorophyll *a* concentrations.

(S.D.) = 0.4; and 5.1 mg BOD L^{-1}, S.D. = 0.4 for control and nutrient augmented experimental, respectively).

Fractionation of Phytoplankton and Nonphytoplankton Respiration

Depth-integrated, total community oxygen consumption (O_2 consumed $m^{-2}\ d^{-1}$, notated as TCOC) was regressed against depth-integrated chlorophyll *a* (Chl). If a linear model adequately describes the relationship of respiration to chlorophyll *a* as it did in the BOD-algae experiments, then the *y* intercept (zero chlorophyll) should be nonphytoplankton oxygen consumption (NPOC). If TCOC = R + NPOC and if phytoplankton respiration is proportional to chlorophyll *a*, then $R = Kp*\text{Chl}$, and TCOC = $Kp*\text{Chl}$ + NPOC. A regression of TCOC against chlorophyll *a* should yield a slope, Kp, and an intercept, NPOC. Regressions for the summer data of 1980 and 1981 for the main channel at Alexandria (Alexandria 1), the channel near the Maryland shore (Alexandria 2), Hatton Point, and Hallowing Point are shown in Figure 5. The *y* intercepts should be the NPOC

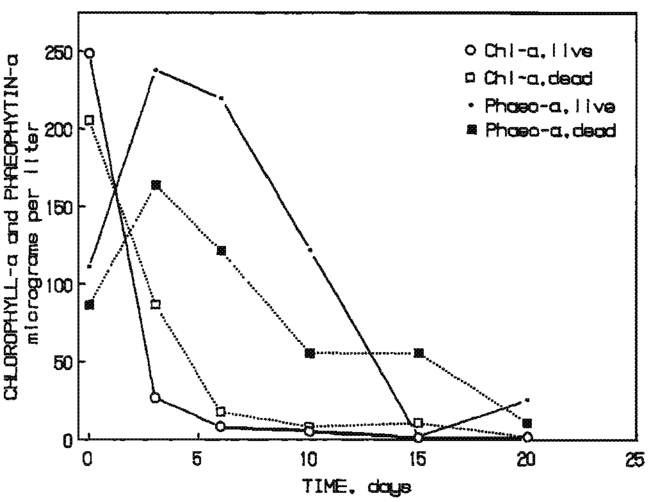

Fig. 3. Degradation of chlorophyll *a* and formation and degradation of phaeophytin *a* during the BOD incubations.

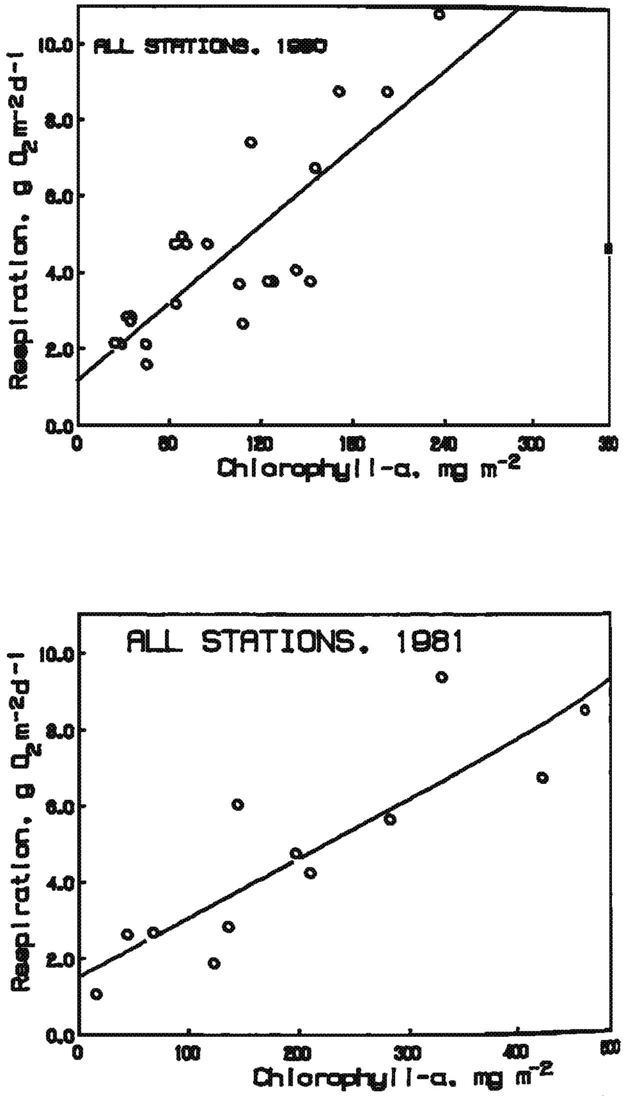

Fig. 5. Regression of total community oxygen consumption against depth-integrated chlorophyll *a* using 1980 and 1981 summer data for the combined Alexandria 1, Alexandria 2, Hatton Point, and Hallowing Point stations.

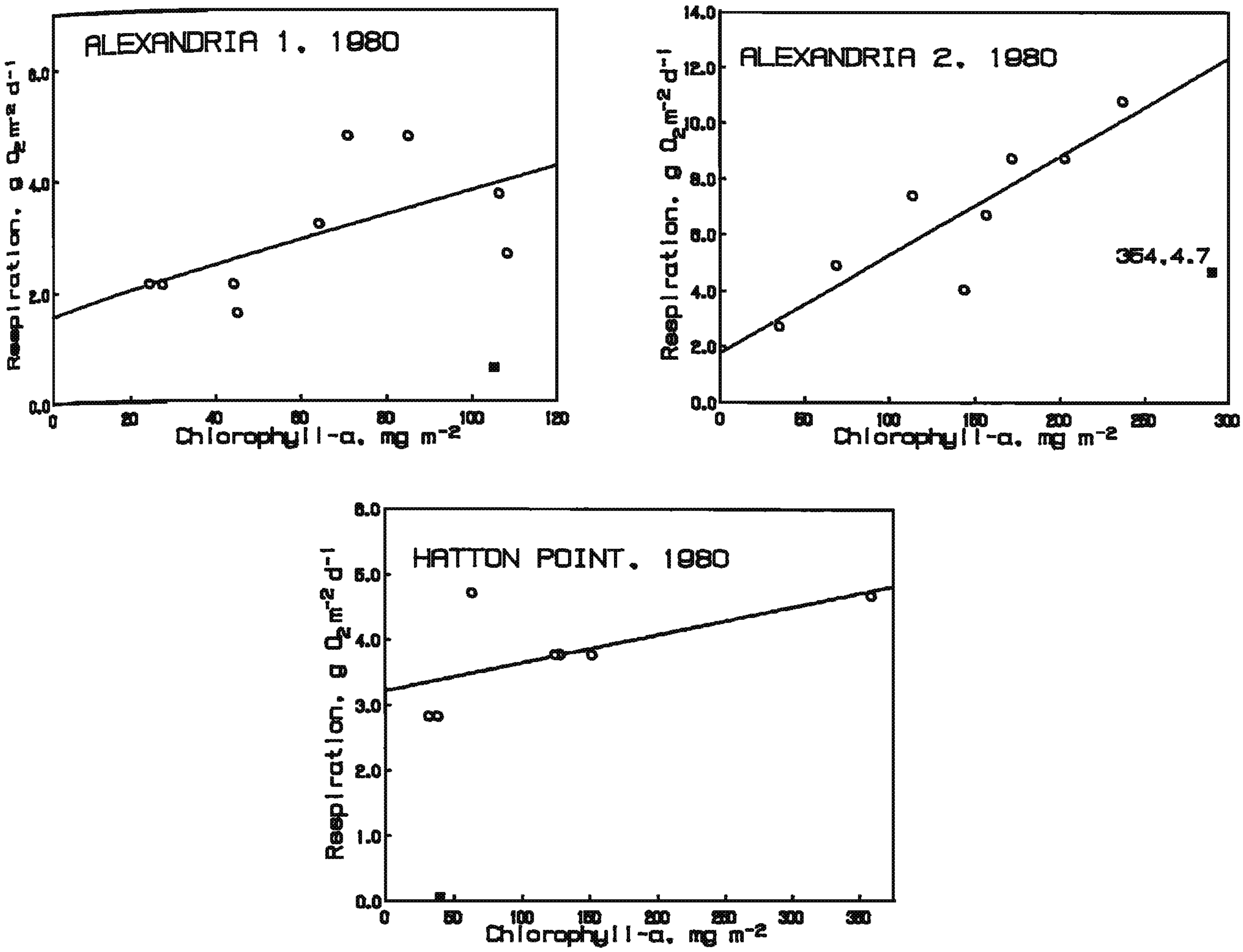

Fig. 6. Representative regressions of total community oxygen consumption against depth-integrated chlorophyll *a* excluding Hallowing Point. Solid squares were considered outliers and were not included in the regression. Labels above solid squares denote x, y values of outliers falling outside of scale limits.

representative of each of the two summers. The regressions for representative stations are shown in Figure 6. There are some single extreme outliers. Outliers were determined as any chlorophyll *a* or respiration measurement that was beyond 1.5 times the interquartile range and plotted as solid squares if within the range of the x and y axis scales. Otherwise, they are plotted with the value printed above the point. The regression for Hallowing Point was not significant, and data scatter precluded further analyses. The intercept is different for each station (Table 2), but when the volume based intercept is obtained by dividing by station depth, the results show similar NPOC for each station for 1980 (Table 2). The hydraulic residence time of a water parcel in the reach between Alexandria 1 (and Alexandria 2) and Hatton Point was short, less than 3 days during August of 1980 (discharge = 96.2 m^3 s^{-1}) [*Cohen et al.*, 1984]. Therefore it is not surprising that the stations had similar volume-based nonphytoplankton respiration (0.71–0.82 g O_2 per m^3 d^{-1}). The same analysis for the summer of 1981 yields dramatically different volume based intercepts. This may be due to the paucity of 1981 data or to the considerably lower flow of August 1981 (53.1 m^3 s^{-1}), permitting water parcels the time to differentiate. The coefficient (slope) for phytoplankton respiration for the combined stations and summers, K_p, is 0.014 g O_2 per mg chlorophyll *a* d^{-1} (0.88 mg O_2 per mg chlorophyll *a* h^{-1} ranging from 0.2 to 1.5 mg O_2 per mg chlorophyll *a* h^{-1} for individual stations and summers). Calculations based on the zero chlorophyll *a* intercepts (y intercepts) and on the oxygen per chlorophyll coefficient show that in the tidal, fresh Potomac River in July and August, nonphytoplankton oxygen consumption is 100% of community respiration when no phytoplankton are present, 50% at levels of 200 mg chlorophyll *a* m^{-2} and approximately 25% at 600 mg m^{-2}.

There must be independent verification that these respiration-chlorophyll *a*, y intercepts are reasonable approximations of NPOC. Therefore I compared the calculated NPOC to the respiration measured during summer productivity experiments that were performed at times of low concentrations of chlorophyll *a*. If phytoplankton biomass was low enough, then most of the observed oxygen consumption would be due to nonphytoplankton sinks and should match that station's regression-based NPOC. Lowest, productivity-associated chlorophyll *a* concentrations were 7.4 $\mu g\ L^{-1}$ on July 1, 1981; 12.5 $\mu g\ L^{-1}$ on August 25, 1981; and 8.2 $\mu g\ L^{-1}$ on August 20, 1980, for Alexandria 1, Alexandria 2, and Hatton Point, respectively. Each chlorophyll value is less than 10% of the maximum values attained during productiv-

TABLE 2. Parameters for Regressions of Respiration Against Depth-Integrated Chlorophyll *a*

Station	Year (July–Aug.)	Volume-Based Intercept, $g\ O_2\ m^{-3}\ d^{-1}$	Area-Based Intercept, $g\ O_2\ m^{-2}\ d^{-1}$	K_p, $g\ O_2\ m^{-2}\ d^{-1}$ per mg chlorophyll *a* m^{-2}	K_p, $mg\ O_2\ m^{-2}\ h^{-1}$ per mg chlorophyll *a* m^{-2}	*R*	Standard Error	
							Intercept	Slope
All stations	1980/1981	0.82	2.46	0.014	0.58	0.72		
All stations	1980		1.17	0.033	1.33	0.70	0.58	0.005
All stations	1981		1.52	0.016	0.67	0.86	0.70	0.003
Alexandria 1	1980	0.72	1.56	0.022	0.92	0.59	0.81	0.011
Alexandria 2	1980	0.71	1.79	0.035	1.5	0.87	1.26	0.008
Hatton Point	1980	0.81	3.18	0.0043	0.18	0.65	0.38	0.002
Alexandria 1	1981	0.99	1.35	0.016	0.67	0.94	0.57	0.004
Alexandria 2	1981	1.14	3.22	0.012	0.50	0.74	2.24	0.008
Hatton Point	1981	0.05	0.11	0.018	0.75	0.99	0.51	0.002
Hallowing Point	1981	0.08	0.45	0.033	1.38	0.98	1.67	0.05

Intercept was divided by average cross-section depth to obtain the volume-based intercept. *R* is the estimate of correlation between *x* and *y*. K_p is the slope or regression coefficient. Alexandria 1, 2, and Hatton Point each had one outlier that was not used in the regression.

ity experiments at those stations in 1980 and 1981. Discharge on each date was similar to the monthly average so that wasteload dilution would not be a factor changing NPOC. The depth-integrated respirations for those dates and their respective *y* intercepts are shown in Figure 7. A two-sample, *t* test analysis shows that the hypothesis that the means of the observed and the intercept based respiration are equal can be accepted at the 5% level.

Relation of Respiration to Primary Productivity

If respiration was a function of primary productivity, then dark bottle oxygen consumption would not have to be measured. There is no function that describes the respiration-productivity relationship adequately, although it is reasonable to assume that phytoplankton oxygen consumption is proportional to primary productivity [*Talling et al.*, 1973]. I examined this hypothesis by subtracting the respiration–chlorophyll *a*, *y* intercept from total community oxygen consumption and regressing the remainder, phytoplankton respiration, against depth integrated primary productivity (Table 3). Data scatter for Hatton Point was too large for meaningful slope determination. Depth-integrated phytoplankton respiration was 24% of depth-integrated, gross primary productivity at Alexandria 1 ($r^2 = 0.87$) and 38% at Alexandria 2 ($r^2 = 0.78$).

Chlorophyll *a* may be a hidden variable in the gross primary productivity term. As phytoplankton biomass increases, so will primary productivity and respiration. Therefore it is necessary to examine productivity normalized to biomass. In addition, many researchers have described respiration as a function of maximum assimilation number P_{max} (maximum rate of production per unit chlorophyll) as determined from the productivity-light relationship [*Ganf*, 1980]. Table 3 shows the results of regressing volume based respiration normalized to chlorophyll *a* against the maximum assimilation number. Outliers are indicated on the graphs. Respiration was 1% of P_{max} for all 1980 and 1981 data at Alexandria 1, 2% at Alexandria 2, 3% for Alexandria 1 in 1981, 3% for Hatton Point in 1981, and 1% for all stations data in 1981. Alexandria 2 had a negative *y* intercept.

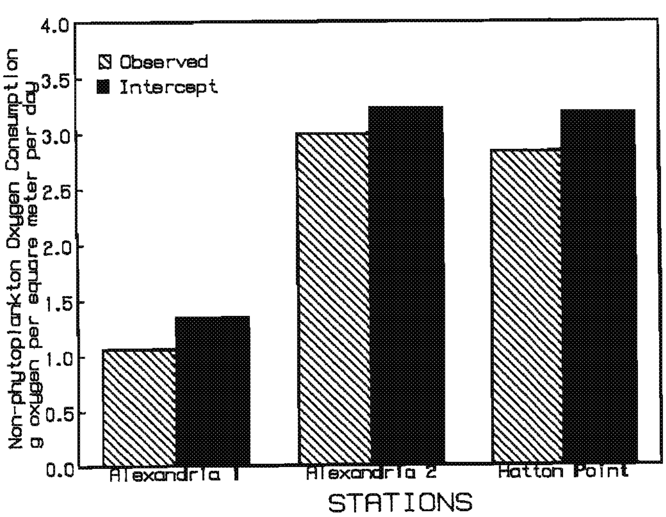

Fig. 7. Comparison of nonphytoplankton O_2 consumption measured at times of low phytoplankton abundance to nonphytoplankton O_2 consumption determined from the *y* intercepts of the relationship of total community oxygen consumption to depth-integrated chlorophyll *a*.

CONCLUSION

The experiments on effects of algae on BOD confirm some of the results of *Fitzgerald* [1964]: algae increase apparent BOD over background levels. In contrast to Fitzgerald's findings, dead algae did not exert a higher oxygen demand than live algae. The type and magnitude of oxygen demand exerted by algae depends on whether the process is dominated by dark respiration of algae or bacterial oxidation of algal biomass. Because (1) chlorophyll *a* degraded to phaeopigment in 3 days, (2) total pigments were less than 10% of initial concentrations by day 20 of the incubation, and (3) live and dead algae yielded similar 20-day UBOD and CBOD, it is reasonable to suggest that the algae died early in the incubation and the oxygen was depleted by bacterial oxidation of algae biomass.

UBOD and CBOD were linearly related to chlorophyll *a* concentration. For every increase of 10 mg L^{-1} of chlorophyll *a*, there was an increase of approximately 2 mg L^{-1} in UBOD and CBOD. Perhaps regressions of BOD against chlorophyll *a* during "critical periods" of low, nearly steady discharges and waste loads would yield a *y* intercept that

TABLE 3. Parameters for Regressions of Algal Respiration Against Gross Primary Productivity (GPP) and Maximum Assimilation P_{max}

Station	Date	Regression Coefficient (Slope)	Intercept	r^2	Number of Outliers	Number of Data Points n
		Respiration Versus GPP				
Alexandria 1	1980	0.24	0.18	0.87	1	10
Alexandria 2	1980	0.38	0.13	0.78	1	9
		Respiration Versus P_{max}				
All data	1980	0.014	0.38	0.70	0	37
Alexandria 1	1980	0.012	0.33	0.54	0	10
Alexandria 2	1980	0.017	0.12	0.91	1	9
All data	1981	0.013	0.13	0.65	0	15
Alexandria 1	1981	0.026	0.49	0.94	0	4
Hatton Point	1981	0.025	0.12	0.91	0	4

represents BOD unaffected by algae. *Welch* [1969] has performed such a regression in log-log space but has not utilized the zero chlorophyll, y intercept concept presented here to separate phytoplankton from nonphytoplankton respiration.

A linear model seems to describe the relationship of total community oxygen consumption to chlorophyll a adequately, as might be anticipated by the results of the BOD-chlorophyll relationship discussed above. These results also suggest that there may be a linear relationship between phytoplankton respiration and chlorophyll a. The y intercept values closely match the measurements of community oxygen consumption when chlorophyll concentrations were very low.

Thomann [1972] recommended using *Guillard and Ryther*'s [1962] algal culture-derived estimate of algal respiration of 1 mg O_2 L^{-1} h^{-1} per mg chlorophyll a L^{-1} (range = 0.1 to 4.5 [*Ganf*, 1980]). This value is close to the range of 0.2 to 1.5 mg O_2 per mg chlorophyll a h^{-1} that I determined using Potomac data. If labor and time intensive productivity and respiration experiments cannot be performed, the values of the coefficient suggested by *Guillard and Ryther* [1962] and *Thomann* [1972] or reported in this paper may be a reasonable alternative for estimating phytoplankton respiration from chlorophyll a data.

Researchers, using several methods, have estimated nonphytoplankton O_2 consumption to be some constant proportion of total community oxygen consumption: 70% [*Ganf*, 1980] in Kiev Reservoir; bacterial respiration to be 30% of TCOC in Marion Lake [*Hargrave*, 1969], and 50% of total TCOC [*Ganf*, 1974]. From these Potomac data, it does not seem acceptable to present NPOC as a constant proportion of community oxygen consumption, even if NPOC is constant. The proportion of community respiration will change as the phytoplankton biomass changes.

Once NPOC has been subtracted from community respiration the remainder, algal respiration, can be related to primary productivity. *Riley* [1946] and *Steeman-Nielsen and Hansen* [1959] have suggested that respiration is 10% of P_{max}, and *Harris and Piccinin* [1977] have suggested it is 3–7% of P_{max}. It would be useful if these relationships held true, but respiration is a very complex process which may or may not be amenable to simple analyses. There are conflicting reports concerning the magnitude of respiration. *Westlake* [1980] doubted that respiration is a constant fraction of gross primary productivity. Respiration that occurs in dark bottles may or may not be repressed or completely inhibited in the light [*Brown and Tregunna*, 1967; *Raven*, 1972; *Lex et al.*, 1972] and may vary with respect to light history [*Padan et al.*, 1971; *Stone and Ganf*, 1981]. Assuming light respiration to be the same as dark respiration when light respiration is actually repressed would result in severe overestimates of gross productivity. A distinctly separate oxygen consuming process, photorespiration, may dominate oxygen consumption under high light and low CO_2 levels [e.g., *Goldsworthy*, 1970; *Lex et al.*, 1972]. Photorespiration might increase with light until it is higher than dark respiration, resulting in underestimates of gross productivity. Therefore it is not surprising that there was considerable data scatter in the relationship of phytoplankton respiration to depth integrated gross primary productivity and to P_{max}. Nevertheless, the analyses worked well for Alexandria 1 and for Alexandria 2. Phytoplankton respiration was 1/4 to 1/3 of gross primary productivity. Phytoplankton respiration was 1–3% of P_{max}.

Reports on the relationship of photosynthesis to light, mixing and time can be found in every marine biology, ecology, freshwater ecology, and wastewater engineering journal. Errors in estimates of productivity may be large due to poorly known and researched characteristics of respiration. Future emphasis on productivity-DO studies should be directed toward resolution of problems concerning respiration, such as presence and magnitude of photorespiration, and the relationship of dark to light respiration.

SUMMARY

BOD was found to increase linearly with chlorophyll a concentration. Short-term dark bottle incubations of river water provided measurements of total community oxygen consumption (TCOC), not phytoplankton respiration. TCOC could be fractionated into its nonphytoplankton and phytoplankton components by regressions of TCOC against chlorophyll a concentration. Phytoplankton respiration was 1/4 to 1/3 of gross primary productivity and could be approximated as 0.88 mg O_2 consumed mg^{-1} chlorophyll a h^{-1}.

The overall results, with their large standard errors for slopes and intercepts, can be considered a conceptual development for the fractionation of algal and nonalgal respiration. More accurate results should come about with data collected for the sole objective of substantiating these ideas.

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